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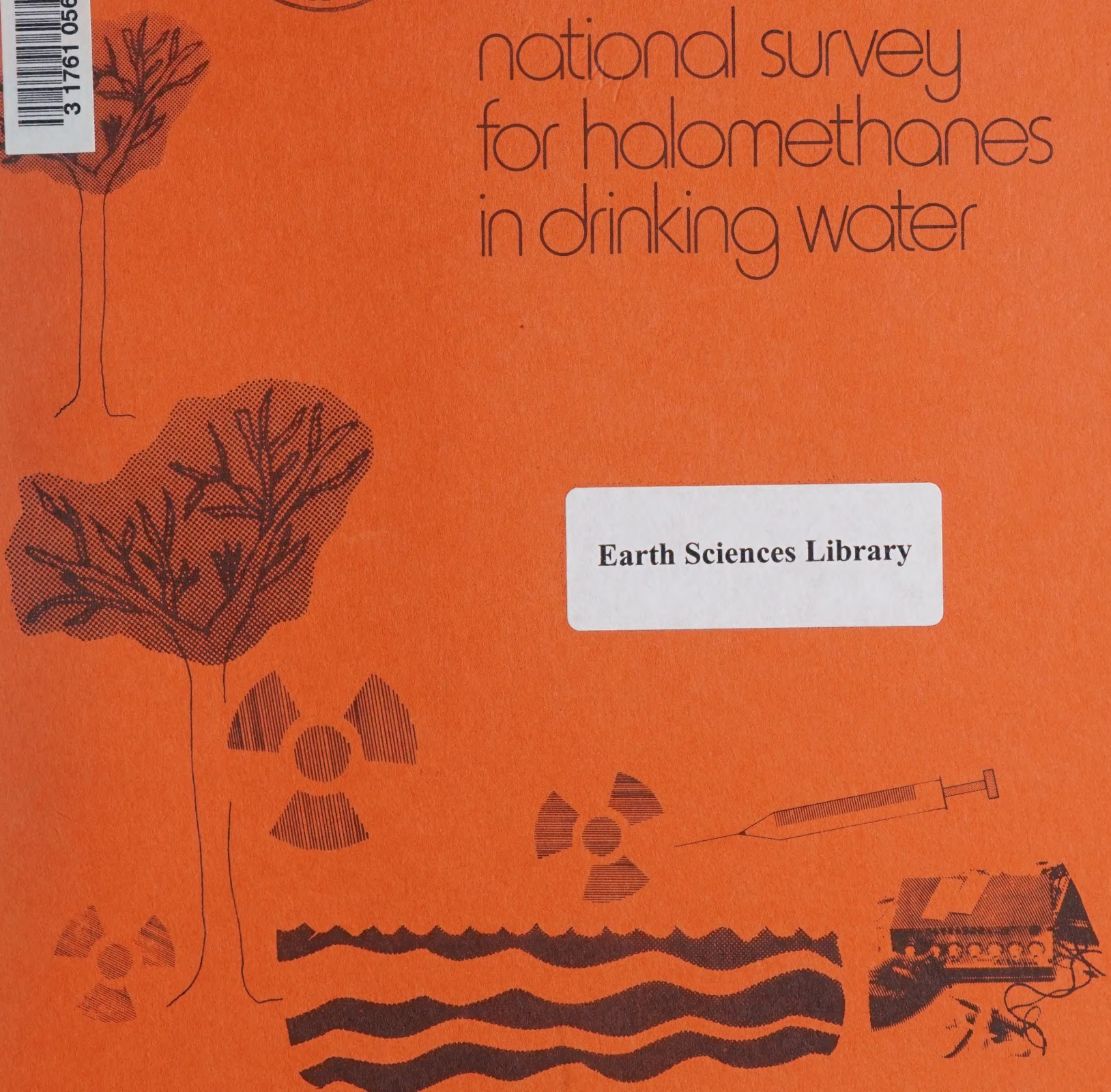

NATIONAL SURVEY FOR HALOMETHANES IN DRINKING WATER

Environmental Health Directorate

Health Protection Branch

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SUMMARY

A national survey for halomethanes in drinking water was carried out in seventy Canadian municipalities. The objectives of the survey were to determine halomethane levels in drinking water supplies across Canada and to relate these levels, if possible, to the type of raw water supply, water treatment and total organic content. The four trihalomethanes: chloroform, bromodichloromethane, chlorodibromomethane and bromoform, were not found or were present in low concentrations in the raw waters but were present in finished waters which had been chlorinated as part of the water treatment process. Concentrations of these compounds found in samples from the finished water distribution systems were: chloroform, 0 to 121 µg/ℓ, median 13 µg/ℓ; bromodichloromethane, 0 to 33 µg/ℓ, median 1.4 µg/ℓ; chlorodibromomethane, 0 to 6.2 µg/ℓ, median 0.1 µg/ℓ; bromoform, 0 to 0.2 µg/ℓ, median <0.01 µg/ℓ. Halomethane levels in water in the distribution system were found to be significantly higher than in water sampled at the treatment plant.

The raw water source was found to influence the levels of halomethanes in finished waters. Halomethane concentrations were similar in finished waters when the raw water source was a river or lake but halomethane levels for well sources were significantly lower.

Weak correlations were found between halomethane concentrations and chlorine demand, chlorine dosage and the raw water total organic carbon content. Raw water pH and hardness had no obvious effect on halomethane levels in finished water.

RÉSUMÉ

Une enquête à l'échelle nationale sur la teneur en halométhanes des eaux potables a été effectuée dans sept municipalités canadiennes. Cette enquête avait pour but de déterminer les niveaux de ces composés dans l'eau potable et d'en faire la corrélation, si possible, avec le type d'approvisionnement en eaux naturelles, leur mode de traitement et leur teneur totale en matière organique. Dans les eaux naturelles, la concentration des quatre dérivés, chloroforme, bromodichlorométhane, chlorodibromométhane et bromoforme, était nulle ou très faible: ces derniers étaient cependant nettement présents dans les eaux dont la chlorination faisait partie de leur traitement. La concentration en halométhanes mesurée dans des échantillons d'eau traitée et prélevés dans les conduits d'alimentation se lisait ainsi: de 0 à 121 µg/ℓ, médiane de 13 µg/ℓ, pour le chloroforme; de 0 à 33 µg/ℓ, médiane de 1,4 µg/ℓ, pour le bromodichlorométhane; de 0 à 6,2 µg/ℓ, médiane de 0,1 µg/ℓ, pour le chlorodibromométhane; de 0 à 0,2 µg/ℓ, médiane de <0,01 µg/ℓ, pour le bromoforme. Les niveaux d'halométhanes dans les eaux prélevées dans les conduites d'alimentation étaient nettement plus élevés que dans les échantillons prélevés à l'usine de traitement.

On a trouvé que l'origine de l'eau naturelle influence les niveaux de ces composés dans l'eau traitée. Leur concentration était comparable dans les eaux traitées quand celles-ci provenaient d'une rivière ou d'un lac alors qu'elle était sensiblement plus basse lorsqu'elles provenaient d'un puits.

Peu de corrélation fut trouvée entre les concentrations d'halométhanes et la demande en chlore, le dosage de ce dernier ainsi que la totalité de la matière organique de l'eau naturelle, le pH et la dureté de l'eau naturelle ne semblaient pas influencer de façon évidente les niveaux d'halométhanes lors du traitement chimique de cette dernière.

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INTRODUCTION

It was reported by Rook (1) in 1974 and confirmed by Bellar et al. (2) that the halomethanes, chloroform, bromodichloromethane, chlorodibromomethane and bromoform, were present in treated drinking water and were produced during the water treatment process. Chlorine, which is used to disinfect water and to prevent growth of bacteria, in the distribution system, reacts with naturally occurring organic compounds present in the raw water to produce chloroform. It is thought that the brominated halomethanes are produced by bromine formed by reaction of chlorine with bromide ion present in the raw water (1, 3). Concurrently with these findings, it was reported that a large number of organic compounds had been identified in the New Orleans water supply (4). The United States Environmental Protection Agency (USEPA) responded to these results by initiating a National Organics Reconnaissance Survey of eighty water utilities to determine levels of halomethanes and other organics in U.S. drinking water (5). Simultaneously with this national survey, Region V of the USEPA analysed drinking water from eighty-three utilities within their jurisdiction (6). Since December 1974, the Province of Ontario has also been periodically analysing drinking water for halomethanes and other organics at forty-eight water treatment plants throughout the province (7, 8). Although the Ontario and USEPA surveys differed in some respects in sampling and analytical techniques, it was obvious that the formation of halomethanes was occurring wherever chlorine was used in the water treatment process. In order to assess the levels of halomethanes in Canadian drinking water and to try to correlate these levels with water source and treatment practices, a national survey of seventy municipalities was carried out by IEC, International Environmental Consultants Ltd. for the Health Protection Branch, Department of National Health and Welfare. Some duplicate water samples from the survey were also analysed in the Health Protection Branch laboratories in order to provide an interlaboratory comparison of the analytical results and to compare different detection techniques.

Selection of Sample Locations

The locations were chosen to represent a significant portion of water consumed in Canada and to take into account variations in water quality and drinking water treatment methods. Sample stations were selected on the basis of the following criteria:

1) Provincial boundaries,
2) Population,
3) Drainage basins (major and component),
4) Groundwater sources,
5) Chemistry of water supply,

6) Alternate disinfection methods,

7) Degrees of treatment, and

8) Natural versus artificial dissolved organics.

Current postulations indicate that fulvic acid and humic acids in natural waters are the precursors of halomethanes. Waters containing high concentrations of these organics are frequently low in hardness and alkalinity and are from regions of igneous rock. As water quality parameters may significantly affect the formation of halomethanes, sampling stations were located in most major drainage areas.

Sampling locations were selected to provide a mixture of river, lake and groundwater sources distributed geographically.

Table 1, which follows, shows the seventy municipalities selected. The table shows the drainage basins, sources of water, types of treatment and water quality as expressed by pH and hardness. The information presented in the table was obtained from direct contact with several municipalities and from the 1975 Directory and Environmental Handbook published in Water and Pollution Control.

The number of stations selected in each province was roughly pro rata June 1976 Statistics Canada population estimates. One station was selected for about every 200,000 population in each province, except for Ontario. Since Ontario had already carried out surveys for halomethanes, only a sufficient number of stations were selected for this survey to permit comparison of results. The population coverage for each province has been calculated as:

Newfoundland	20%
Prince Edward Island	16%
Nova Scotia	25%
New Brunswick	32%
Quebec	53%
Ontario	37%
Manitoba	63%
Saskatchewan	37%
Alberta	76%
British Columbia	53%
TOTAL CANADA	38%

Collection of Information on Water Source and Treatment Practices

Initially, each municipality was contacted by telephone to verify the water purification processes used and to learn the names of plant personnel to be contacted during the survey.

TABLE 1

SAMPLING STATION DESCRIPTIONS

Water Supply	Major Drainage Basin	Component Drainage Basin	Population Served	Source			Type Of Treatment	Water pH	Quality Hardness	Notes
				Lake	River	Well				
ONTARIO										
Belleville	Great Lakes	Ontario	35,507	X	X		C, Fi, Fc, Fl, Sed	8.4	126	
Brantford	Great Lakes	Grand	70,000		X		C, Fi, Fc, Fl, Sed	8.1	250	
Cayuga	Great Lakes	Grand	1,070		X		Con, Ci	-	-	
Niagara-On-The Lake	Great Lakes	Ontario	3,670		X		C, Carb, Fi	8.0	132	Carbon
Ottawa-Carleton	St. Lawrence	Ottawa	442,000		X		C, Fi, Fc, Fl	7.2	30	Soft
Smiths Falls	St. Lawrence	Ottawa	11,812		X		C, Fi, Fc, Fl, Sed	7.9	120	
Sudbury	Great Lakes	Huron	91,500	X	X		C, Fl, Fi, Sed	6.6	50	
Thunder Bay	Great Lakes	Superior	102,529	X			C	7.5	48	
Toronto	Great Lakes	Ontario	2,173,000	X			C, Fc, Fi, Fl, Sed	7.3	135	
Windsor	Great Lakes	Erie	188,900	X			C, Fc, Fi, Fl, Sed	7.5	106	
Barrie	Great Lakes	Severn	30,756			X	C	7.8	200	Added because well
MANITOBA										
Brandon	Lake Winnipeg	Assiniboine	36,000		X		C, Fi, Fc, Fl, S	7.7	320	
Portage La Prairie	Lake Winnipeg	Assiniboine	14,000		X		C, Fi, S, Sed	8.3	345	
Selkirk	Lake Winnipeg	Red	10,000			X	C, S	7.3	554	High Hardness
Swan River	Lake Winnipeg	Winnipegosis	4,000			X	C, A, I, Fl, Sed	7.2	452	
Winnipeg	Lake Winnipeg	Winnipeg	577,923	X			C, Fl	7.7	74	
SASKATCHEWAN										
Prince Albert	Lake Winnipeg	Saskatchewan	30,000		X		C, Fi, Fl, Sed	8.0	-	
Regina	Lake Winnipeg	Qu'Appelle	148,200	X		X	C, Fi, Fc	7.5	275	
Saskatoon	Lake Winnipeg	South Sask.	134,000		X		C, Fi, Fc, Fl, Sed, S	9.1	95	
Swift Current	Lake Winnipeg	South Sask.	16,000		X		C, Fi, Fl, Fc	8.0	300	
Yorkton	Lake Winnipeg	Assiniboine	14,500			X	C, Fi, A, I	7.5	686	High hardness
ALBERTA										
Calgary	Lake Winnipeg	South Sask.	457,112		X		C, Fi, Fc, Sed	8.3	200	
Edmonton	Lake Winnipeg	North Sask.	530,000		X		C, Fi, Fc, Fl, Sed, S	9.0	80	
Grand Prairie	MacKenzie	Peace	16,618		X		C, Fi, Fc, Fl, Sed	8.0	100	
High Prairie	MacKenzie	Athabaska	5,000			X	C, Fi, A, I	-	-	
Lethbridge	Lake Winnipeg	South Sask.	45,000		X		C, Fi, Fc, Sed	8.0	160	
Medicine Hat	Lake Winnipeg	South Sask.	301,000		X		C, Fi, Fc	8.0	160	
Vermillion	Lake Winnipeg	North Sask.	2,969			X	C, I	7.6	190	
BRITISH COLUMBIA										
Dawson Creek	MacKenzie	Peace	18,000		X		C, Fi, Fc	7.8	160	
Kamloops	Fraser	Thompson	28,000		X		C, Dl	7.4	40	
Kelowna	Columbia	Okanagan	21,000	X			C, Fl	7.9	115	
Nanaimo	Pacific S.B.	-	38,000		X		C	7.1	18	
Penticton	Columbia	Okanagan	50,000	X	X		C	7.2	20	Lake standby
Prince George	Fraser	Fraser	45,000		X	X	C, Fl	7.5	175	
Vancouver (Greater)	Pacific S.B.	-	1,000,000		X		C	6.3	5	
Vancouver (North)	Pacific S.B.	-	41,400		X		C	6.3	6	
Victoria	Pacific S.B.	-	75,000				C, Fi	7.7	20	

TABLE 1 (continued)

Water Supply	Major Drainage Basin	Component Drainage Basin	Population Served	Source			Type Of Treatment	Water pH	Quality Hardness	Notes
				Lake	River	Well				
NEWFOUNDLAND										
Clarenville	Atlantic S.B.		1,900		X		C, Fi, Fc, I	6.0	10	High Colour
Grand Falls	Exploits	Exploits	9,153		X		C, Fi	-	-	
St. John's	Atlantic S.B.		97,550	X			C	6.0	1	
PRINCE EDWARD ISLAND										
Charlottetown	Atlantic S.B.		19,500			X	C, Fl	-	-	
NOVA SCOTIA										
Dartmouth	Atlantic S.B.		72,000	X			C, Fl	7.0	6	
Halifax	Atlantic S.B.		111,500	X			C, Fl, Lime	6.5	2	
Port Hawkesbury	Atlantic S.B.		4,000	X			C, Fi, Fc, Fl, Sed	6.3	30	
Truro	Atlantic S.B.		13,268		X	X	C	7.0	15	High Colour
NEW BRUNSWICK										
Bathurst	Atlantic S.B.		16,674			Spring	C, Fc	7.3	100	
Fredericton	Atlantic S.B.		44,000			X	C, A	7.2	100	
Moncton	Atlantic S.B.	Petitcodiac	58,000		X		C, Fl	6.8	22	
Saint John	Atlantic S.B.		103,000	X			C	6.7	20	
QUEBEC										
Cap-de-la-Madeleine	St. Lawrence	St. Maurice	33,000			X	C	-	-	
Drummondville	St. Lawrence	St. Francis	44,200		X		C, Fi, Fc, Sed	7.0	45	Ozone
Granby	St. Lawrence	Yamaska	34,000		X		C, Fi, Fc, Sed	7.3	55	High Colour
Hudson	St. Lawrence	Ottawa	4,500			X	C	-	150	
Lachine	St. Lawrence	St. Lawrence	73,900		X		Con, Fi	6.9	60	
Laval	St. Lawrence	St. Lawrence	250,000		X		C, Fi, Fc, Fl, Sed	8.3	60	Ozone
Levis	St. Lawrence	St. Lawrence	23,300		X		C, Fi, Fc, Sed	8.0	100	
Longueuil	St. Lawrence	St. Lawrence	220,000		X		C, Fi, Fe, Sed	7.8	140	
Montreal	St. Lawrence	St. Lawrence	1,880,000		X		C, Fi,	7.9	127	
Magog	St. Lawrence	Memphre-magog	15,155	X			C	10.0	77	
Hull-Gatineau	St. Lawrence	Ottawa	100,000				C, Fi, Fc, Sed	7.6	-	
Pierrefonds	St. Lawrence	St. Lawrence	70,000		X		Con, Fi			Ozone
Quebec	St. Lawrence	St. Charles	225,000	X	X		C, Fi, Fc, Sed	7.2	24	Ozone
Rimouski	Atlantic S.B.	St. Lawrence	32,716	X	X		C	8.1	90	
Riviere du Loup	St. Lawrence	R.-du-Loup	15,000	X	X		C, Fe, Fi, Sed	9.0	30	High Colour
Shawinigan	St. Lawrence	St. Maurice	44,000	X			C, Fi	7.0	20	Soft
Sherbrooke	St. Lawrence	Memphre-magog	92,000	X			C	7.3	65	Ozone
Thetford Mines	St. Lawrence	St. Francis	26,000	X			C	7.5	28	
Trois Rivieres	St. Lawrence	St. Maurice	60,000		X		C, Fc, Fi, Fl, N	6.5	15	H. Colour, soft
Windsor	St. Lawrence	St. Francis	6,100		X		C, Fi, Fc, Sed	7.2	50	
St. Eustache	St. Lawrence	St. Lawrence	5,000		X		Con, Fi	-	-	Ozone

Detailed questionnaires on water treatment processes and operating practices at each municipality and covering letters briefly describing the purpose of the survey and requesting the cooperation of municipal officials were then sent to each municipality in the survey. Examples of questionnaires and covering letters are included in Appendix 1. The actual date and time of the sampling visit was confirmed by telephone by the field technologist approximately 48 hours in advance.

Field data sheets were prepared to record the actual plant operating conditions at the time of sampling and the locations of each sampling point in the event that these locations might be resampled sometime in the future.

At each municipality, the field technologist reviewed the questionnaire with water plant personnel to ensure completeness. The field data sheet was completed, giving the most recent chemical analysis and dosage rates of chemicals used in the water treatment.

Sample Collection

In order to minimize variations in sampling technique, the number of persons involved in sampling was kept to a minimum. One technologist collected samples in Ontario and Western Canada, a second collected samples in Quebec and the Maritime Provinces, and a third technologist collected samples in Newfoundland.

To ensure consistent sampling techniques at each municipality, specific sampling procedures were prepared and reviewed in detail with the technologists conducting the sampling. Duplicate samples were collected at the following four locations in each municipality:

1) Raw water intake, prior to prechlorination.
2) Treated water, immediately after all forms of treatment.
3) Station 1, a public building about 1/2 mile from the filtration plant.
4) Station 2, a public building about 1 mile from the plant.

In some localities, it was not possible to adhere completely to the recommended sampling locations. Deviations were recorded on the field data sheet and are discussed in the next section.

The preparation of sample bottles was centralised to minimize the possibility of contamination during sample bottle preparation. For all sample bottles used prior to 31 December, 1976, sodium thiosulfate powder (ca. 1 mg) was added to each sample bottle prior to being shipped to the field technologist. In order to simplify preparation of sample bottles, after 31 December 1976, sodium thiosulfate (1 mg) was added to each bottle in

solution form (1 ml = 2 mg sodium thiosulfate) by titrating 0.5 ml of solution into each bottle. The water of solution was evaporated by drying in an oven at 50°C for 2 hours. The bottles were tightly capped until used for collection for water samples. Immediately prior to collection of the sample, all bottles were labelled with city, date, sample source, and analysis to be performed. Samples were then collected directly into the sample bottles. Special care was taken to ensure that the filled bottles did not contain any air space. Samples were shipped by air express and by courier in heavy plastic coolers containing gel type freezer packs. Despite being well-packed, a few glass sample bottles cracked or broke in shipment by air express. Upon receipt at the laboratories, the samples were refrigerated at 4°C until analysed.

At Hudson (Quebec) and Cap de la Madeleine, water supply is from wells and no treatment of the water supply is employed during the winter months, although chlorination is practiced during the summer months. As a result, samples were only taken at Stations 1 and 2, and at the pumping station for a total of 3 sampling locations, instead of the usual 4. At Prince George, B.C., both chlorine and fluoride are added to the raw water in the well and at Pierrefonds, which obtains raw water from Riviere des Prairies, the intake water is prechlorinated. As a result, it was not possible to obtain an untreated water sample at these municipalities.

In general, Stations 1 and 2 were selected approximately 0.5 to 1 mile from the treatment facility, unless otherwise indicated on the field data sheet. For example, sampling in Winnipeg required special arrangements, as the city water supply is from Shoal Lake, some 110 miles east of the city. The water is prechlorinated at the Shoal Lake intake station and then rechlorinated at the distribution centre in the city. Samples of raw water were taken before chlorination at Shoal Lake. The treated water sample was taken at the distribution centre in Winnipeg after rechlorination. Stations 1 and 2 were selected approximately 0.5 and 1 mile from the distribution centre in Winnipeg.

Some difficulty was encountered in sampling Grand Falls, Newfoundland. As there was no outlet on the water main, prior to chlorination, the "raw water" sample was obtained from an unchlorinated branch line on the outskirts of Grand Falls. The "treated" water sample was taken at a school approximately 3/4 mile from the chlorination system, as no outlet was available prior to the school. The Station 1 and 2 samples were taken approximately 0.5 and 1 mile from the school respectively. Based on the pH of the Station 2 sample, it is likely that this sample was from a different water source. Subsequent analysis appears to confirm this as the halomethane content of Stations 1 and 2 are very different and suggest that the Station 2 sample came from an unchlorinated source.

In some municipalities, several raw water sources feed the city water system. As a result, for these municipalities water samples taken at Stations 1 and 2 may have originated from a water supply different from that sampled for raw and treated water. At each station, the field technologists inquired about the number and location of other water sources and attempted to avoid cross-sampling of water supplies when sampling. To ascertain exactly the potential for cross-sampling of water supplies would require examination of the plans for the water supply system of each municipality. Based on the information gathered by the field technologists, it is possible that cross-sampling of water supplies could have occurred at the following municipalities: Sudbury, Hudson, Trois Rivieres, Cap de la Madeleine, Truro, Dartmouth, Yorkton, Prince George, and Grand Falls. Sampling of different water supplies at all other municipalities is unlikely.

Analytical Procedures for Halomethanes

The survey samples were analysed for halomethanes by the contractor using both direct aqueous injection and gas sparging. The gas chromatograph used was a Hewlett Packard 5840A equipped with a ^{63}Ni electron-capture detector and computerized control system and readout. For direct aqueous injection, a stainless steel column 3' x 1/16" packed with 4% SE-30 on Chromosorb-P (60/80 mesh) as recommended by Bellar and Lichtenberg (9) for the sparge technique was used initially. Bellar and Lichtenberg used this column in conjunction with flame ionization and microcoulometric detectors with nitrogen carrier gas. Although not recommended for an electron capture detector with argon-methane carrier gas, this column was found to give some response for the halomethanes. Although the $CHClBr_2$ and $CHBr_3$ peaks were superimposed on a wide water band, the results were reasonably reproducible and provided adequate sensitivity for the four halomethanes.

A sample volume of only 5 μℓ was used to keep the water interference at an acceptable level. Subsequently, a decision was made to change the carrier gas to pure argon and to introduce the argon-methane mixture into the system between the end of the column and the detector. This change solved all the previous problems which had been caused by the presence of methane in the column. With the methane effects removed, the chromatogram baselines became extremely steady and sensitivities and reproducibilities for all halomethanes improved considerably. Complete analytical parameters for the direct injection technique using the SE-30 column are given in Table 2. All direct injection analyses performed prior to 31 December, 1976, were performed using these parameters.

Continued research on columns resulted in the commissioning of a Tenax GC column early in January 1977. This column had the advantage that it could be used for both direct injection and sparging programs, thus eliminating the downtime required for conditioning of replacement columns when changing from direct injection to sparging or vice-versa.

The analytical parameters for the injection technique using the Tenax column are presented in Table 2. All the samples collected in January and February 1977 were analyzed immediately using the Tenax column. The samples collected prior to 31 December, 1976 were reanalyzed using the Tenax column.

For samples analyzed by the contractor by gas sparging, the sparging apparatus described by Bellar and Lichtenberg (9) was purchased from the Cincinnati Valve Co. and used in much the same manner as described by Bellar and Lichtenberg. The main modification was the method of introduction and removal of the sample.

Whereas Bellar and Lichtenberg used removable syringes and a long needle permanently mounted in the glass sparger, in these analyses the septum was punctured for each sample injection. Sample removal was initially through a long needle permanently mounted through the septum but this was later modified to enable sample removal through a tube located inside the inlet tube of the sparger in conjunction with back pressure of the sparging gas. Neither system was entirely satisfactory as complete removal of a sparged sample was not possible, causing some carry-over of unsparged halomethanes (particularly the bromine compounds) from samples of high concentration.

As sparging efficiency is a function of temperature, gas flow and bubble size produced by the sparger frit, the sparge time had to be determined by experiment. A sparge time of 9 minutes was selected, as essentially all of the chloroform in the standards could be removed in this time. By comparison, Bellar used 12 minutes and Hewlett-Packard recommended 8 minutes.

In previous work reported in the literature, a 5 ml sample was required for the sparge technique due to the insensitivity of the Hall microcoulometric detector. With the electron-capture detector, a 2 ml sample produced sensitivities of 0.1 microgram/litre for chloroform and a 0.01 microgram/litre for the bromine compounds. A disadvantage was the ease of contamination when analyzing a low concentration sample after a high concentration sample. This was particularly true for standards in which bromine compounds were present in amounts much higher than found in the water samples.

The trap and desorber system of Bellar and Lichtenberg proved to be too cumbersome and time consuming to operate and was soon abandoned. The equipment was modified to bypass the trap and introduce the sparged gas directly onto the column (a system now used by Bellar) which was held at 30°C during the sparging operation. In making this change it was found that nitrogen as the sparging gas caused considerable instability in the column. The sparge gas was then changed to Argon 95% - Methane 5% by arranging a bypass for the carrier gas through the sparger before it entered the instrument.

TABLE 2: PARAMETERS FOR DIRECT INJECTION

	SE-30	TENAX GC
Column	Stainless Steel 3' x 1/16" I.D. packed with 4% SE-30 on Chromasorb P (60/80 mesh)	Stainless Steel 6' x 1/8" OD packed with TENAX GC 60/80 mesh
Carrier Gas	Argon 95% - Methane 5% 20 mls./min.	Argon 30 mls./min; Argon 95% - Methane 5% 30 mls./min. introduced before detection
Injector Temperature	150°C	180°C
Detector Temperature	260°C	260°C
Oven Temperature	65°C isothermal for 8 min. Column then cleared at 75°C until water peak disappeared.	Start at 90°C and rate change at 30°C/min. to 135°C At 3.5 mins. rate change at 6°C/min. to 165°C At 12.5 mins. rate change at 30°C/min. to 180°C Hold at 180°C to end of program at 17.5 mins.
Sample Volume	5 microlitres	5 microlitres
Typical Retention Times		
$CHCl_3$	1.34 min.	5.25 min.
$CHCl_2Br$	2.12 min.	8.10 min.
$CHClBr_2$	3.69 min.	11.80 min.
$CHBr_3$	6.80 min.	16.50 min.
Sensitivities, micrograms per litre		
$CHCl_3$	1	0.5*
$CHCl_2Br$	0.5	0.1
$CHClBr_2$	0.1	0.1
$CHBr_3$	5	1

* This figure could have been improved to 0.1 if the area rejection of 500 (as used for the sparge) had been removed from the computer program.

Neither of the column packings recommended by Bellar and Lichtenberg, Chromosorb-101 and 4% SE-30 on Chromosorb-P (NAW), could be made to work satisfactorily with the Argon-Methane carrier gas. Nitrogen, as used by Bellar, could not be used with the electron-capture detector. A column packing of Carbowax was recommended by Hewlett-Packard and was found to be satisfactory. This column was used for the sparge technique up until 31 December, 1976.

A Tenax-GC column was then commissioned and this column was used for the remainder of the program. In addition to providing an extremely stable base-line, it was found that considerable time could be saved by maintaining the oven temperature at 50°C during the sparge instead of the 30°C required for the Carbowax. Tenax-GC did not release chloroform until the column temperature had reached over 100°C. Also contributing to the stable base-line was the change to Argon only as sparge and carrier gas, with introduction of the Argon 95% - Methane 5% mixture just before the detector.

The sparging data can therefore be considered as derived from two different programs. The Carbowax program covers Samples no. 5 - 142 and the Tenax program samples no. 142 - 286. The analytical parameters for the sparging technique are presented in Table 3.

For the samples analyzed by the Department of Health and Welfare by the gas sparging method, a Hewlett-Packard 7620A gas chromatograph coupled to a Hewlett-Packard 3750 integrator was used. The column packing was Tenax-GC, the carrier gas was nitrogen (zero gas grade) and the detector was a Tracor Hall conductivity detector operating in the halogen reductive mode. The full analytical parameters are given in Table 4.

As indicated all the samples collected after 31 December, 1976, were analyzed by the direct injection technique using a Tenax GC column, whereas those collected before 31 December, were analyzed initially on an SE-30 column and subsequently were reanalyzed on the Tenax column. Only the results of direct injection analysis on the Tenax column are presented in Appendix 2, with the exception of samples which were lost due to bottle breakage prior to reanalysis. Results for these samples are from the SE-30 column as noted.

Agreement between results obtained from the two different columns was reasonably good as illustrated below by the chloroform concentrations measured in the Hull samples.

	$CHCl_3$ ($\mu g/\ell$)	
Sample No.	TENAX	SE-30
65	1.2	1.8
66	68	63
67	64	63
68	76	77

TABLE 3: PARAMETERS FOR SPARGING

Column	Stainless Steel 10' x 1/8" O.D. packed with mixed phase 10% Carbowax 20 m + 10% 6-ring polyphenyl ether on 80/100 Chromosorb W-AW	Stainless steel 6' x 1/8" O.D. packed with TENAX-GC 60/80 mesh.
Carrier Gas	Argon 95% - Methane 5% 30 mls./min.	Argon 30 mls./min; Argon 95% - Methane 5% 30 mls./min, introduced before detector.
Injector Temperature	150°C	180°C
Detector Temperature	250°C	260°C
Oven Temperature	Start at 30°C and rate change at 20°C/min. to 70°C. At 8 mins. rate change at 20°C/min to 140°C At 14 mins. rate change at 15°C/min. to 155°C Hold at 155°C to end of program at 20 mins.	Start at 50°C and rate change at 30°C/min. to 120°C At 3 mins. rate change at 6°C/min. to 143°C. At 6.80 mins. rate change at 30°C/min. to 180°C Hold at 180°C to end of program at 16.30 mins.
Sparge Sample Volume	2 ml.	2 ml.
Typical Retention Times		
$CHCl_3$	7.35 min.	7.26 min.
$CHCl_2Br$	11.70 min.	8.96 min.
$CHClBr_2$	14.85 min.	11.15 min.
$CHBr_3$	18.90 min.	15.10 min.
Sensitivities micrograms per litre	Carbowax	TENAX
$CHCl_3$	0.1	0.1
$CHCl_2Br$	0.01	0.01
$CHClBr_2$	0.01	0.01
$CHBr_3$	0.1	0.01

TABLE 4: GAS SPARGING METHOD (HW)

Column: Stainless steel 7' x 1/8" O.D. packed with TENAX-GC 60/80 mesh.

Carrier Gas: Nitrogen, zero grade (Matheson);
90 ml/min. @ 40 psi and <50°C.

Injection Temperature: 150°C.

Oven Temperature: 50 - 115°C. @ 30°/min.
115 - 135°C. @ 6°/min.
135 - 200°C. @ 30°/min.
Hold 200°C. for 2 min.

Detector: Tracor 310 Hall Electrolytic conductivity Detector
utilizing 50/50 IPA/H_2O @ 0.25 ml/min. and
settings; CONDUCTIVITY = 30
ATTENUATION = 1

Furnace Temperature: 860°C.
Hydrogen: 25 ml/min. @ 30 psi.

Sparge: Sample Volume = 5.0 ml.
Gas = Nitrogen zero grade, 40 ml/min. for 10 min.
@ 30 psi. and 30°C.

Typical Retention Times		Sensitivities - µg/ℓ
$CHCl_3$	4.14 min.	0.2
$CHBrCl_2$	5.84 min.	0.1
$CHBr_2Cl$	7.35 min.	0.1
$CHBr_3$	8.29 min.	0.2

Time did not permit an extensive investigation into repeatability of the direct injection procedure for samples, but those which were repeated demonstrated a reasonable agreement. Some examples are shown in Table 5.

In general, replicates were only made if excessive contamination from the previous run was suspected, particularly when a raw water sample was preceded by a Standard such as no. 3A. These are noted in the results presented in Appendix 2.

As stated two types of GC columns, Carbowax and Tenax, were used in the analysis of halomethanes by the sparging technique. The changeover improved the sensitivity of the analysis for bromoform and appeared to give good agreement between results obtained from the different columns as illustrated in Table 6.

TABLE 5: REPEATABILITY OF HALOMETHANE ANALYSIS BY DIRECT INJECTION

		$CHCl_3$ ppb	$CHCl_2Br$ ppb	$CHClBr_2$ ppb	$CHBr_3$ ppb
Windsor, (Ont.) Treated	Original	6.4	2.6	1.4	< 1
	Repeat	7.0	1.4	1.3	1
Fredericton, Stn. 1	Original	6.3	0.7	< 0.1	< 1
	Repeat	7.5	0.6	< 0.1	< 1
Vermillion, Raw	Original	0.7	< 0.1	< 0.1	< 1
	Repeat	0.7	< 0.1	< 0.1	< 1
High Prairie, Stn. 2	Original	5.4	1.6	< 0.1	< 1
	Repeat	5.5	1.4	< 0.1	< 1

Precision of Halomethane Analytical Data

Calculation of the precision of the analytical data is based on repeated analysis of standards throughout the analytical program. The precision or standard deviation for each compound and different method was established by pooling the variances for the various standard concentrations. The calculated estimates of precision from the contractors data are presented in Table 7 for Direct Injection using a Tenax column, Gas Sparging with a Carbowax column and Gas Sparging using a Tenax column. Estimates of precision are presented for comparison of the data from the samples analysed by the Health Protection Branch by Gas Sparging using a Tenax column.

TABLE 6: REPEATABILITY OF HALOMETHANE ANALYSIS BY SPARGING TECHNIQUE

		$CHCl_3$ ppb	$CHCl_2Br$ ppb	$CHClBr_2$ ppb	$CHBr_3$ ppb
Toronto,	Original	5.5	4.9	2.9	< 0.1
Treated	Repeat	5.6	5.4	3.3	< 0.1
Belleville,	Original	64	5.1	0.01	< 0.1
Treated	Repeat*	57	7.0	2.6	0.08
Granby, Stn. 1	Original	< 0.1	0.14	< 0.01	< 0.1
	Repeat	< 0.1	< 0.1	< 0.01	< 0.1
	Repeat	< 0.1	0.13	< 0.01	0.1
Granby, Stn. 2	Original	52	5.2	0.67	0.8
	Repeat	61	5.2	0.44	0.4
Brandon, Stn. 1	Original	14	4.6	0.55	< 0.1
	Repeat	15	5.1	0.8	< 0.1
Portage-la-Prairie	Original	2.6	0.05	0.01	< 0.1
Treated	Repeat	2.0	0.56	0.30	< 0.1
Edmonton, Stn. 2	Original*	10.2	0.64	0.09	< 0.01
	Repeat*	9.8	0.57	0.37	0.02
Grand Prairie,	Original*	24	0.63	0.10	0.14
Treated	Repeat*	24	0.67	0.18	0.04

*Tenax column. All other results from Carbowax column.

Organic Carbon Analysis

Analysis of the halomethane samples for total organic carbon content was performed by the Institute for Environmental Studies of the University of Toronto. The total organic carbon (TOC) concentration was determined by difference from the total carbon and inorganic carbon concentrations in the sample as measured by a Beckman 915 A Carbon Analyzer. This instrument has a sensitivity of 0.4 mg/l.

TABLE 7: COMPARISON OF PRECISION OF HALOMETHANE ANALYSIS BY DIFFERENT METHODS

METHOD / COMPOUND	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
Contractors Data				
Direct Injection - Tenax				
Precision (µg/ℓ)	±1.0	±0.59	±0.37	±0.36
Relative Precision (%)	±2.1	±3.2	±2.4	±2.1
Mean Concentration (µg/ℓ)	47.9	18.6	15.6	17.3
Concentration Range (µg/ℓ)	14.8-74	5.8-29.2	4.9-24.5	5.7-28.8
No. of Observations	52	53	53	46
Gas Sparging - Carbowax				
Precision (µg/ℓ)	±0.97	±0.15	±0.28	±1.1
Relative Precision (%)	±3.3	±0.8	±2.8	±9.5
Mean Concentration (µg/ℓ)	29.4	18.1	10.1	11.6
Concentration Range (µg/ℓ)	7.4-74	4.8-48.6	2.45-24.5	2.9-28.8
No. of Observations	36	36	30	35
Gas Sparging - Tenax				
Precision (µg/ℓ)	±0.36	±0.74	±0.94	±2.0
Relative Precision (%)	±0.8	±4.2	±6.3	±11
Mean Concentration (µg/ℓ)	44.5	17.5	15.0	17.6
Concentration Range (µg/ℓ)	14.8-74	5.8-29.2	4.9-24.5	5.7-28.8
No. of Observations	35	35	36	36
Health Protection Branch Data				
Gas Sparging - Tenax				
Precision (µg/ℓ)	±1.3	±0.39	±0.48	±0.76
Relative Precision (%)	±5	±11	±15	±19
Standard Concentration (µg/ℓ)	26	3.5	3.2	4.0
No. of Observations	35	35	33	30

The results of the analyses as reported by the Institute are presented in Appendix 3. For ease in correlation of the halomethane concentration with organic carbon content, the TOC of each sample has been recorded on the data sheets presented in Appendix 2. The University of Toronto provided data from five repeat analyses of five concentrations of total carbon and inorganic carbon standards ranging from 20 mg/l to 100 mg/l.

The precision of the TOC analyses was calculated to be ± 0.85 mg/l. This estimate is based on individual estimates of precision for both the Total Carbon and Inorganic Carbon channels of the Beckman 915 A Carbon Analyzer.

Effect of Storage on Halomethanes

Difficulties in the development of adequate analytical parameters made it impossible to immediately analyze samples collected in November and early December. As a result, a program to determine the effect of storage on halomethane concentrations was instituted. A dozen samples of treated water were collected simultaneously at the Brantford water treatment plant on 16 December, 1976. The samples were preserved with 1 mg of sodium thiosulphate to minimize the continued reaction of the chlorine residual with organic compounds in the water and stored in a refrigerator under the same conditions as the survey samples.

The first sample was analyzed within a day of collection and the remainder were analyzed at intervals thereafter. In addition to analyzing a new sample each time, the first sample was reanalyzed several times to determine if continued reopening of a partly filled bottle affected the halomethane content of the sample. Table 8 presents the analytical results of the program. Statistical analysis of the gas sparging results was undertaken as the "free" halomethanes measured by the gas sparging technique should be the most affected by extended sample storage. A regression line for the trihalomethane concentrations for the various storage times for each of the four halomethanes was calculated. As the slopes of the lines for all four compounds were not significantly different from zero at the 95% confidence level, it was concluded that no change in halomethane concentrations occurred during storage for up to nine weeks in the absence of free chlorine when stored under refrigerated conditions.

A similar conclusion was obtained by comparing the residual sum of squares about the regression line to the residual sum of squares about the mean concentration for each compound using an "F" Test. The residuals about the regression lines were not significantly different from the residuals about the concentration means, indicating no improvement in fit using the regression line. A statistical summary is presented in Table 9.

TABLE 8: STORAGE EXPERIMENT RESULTS

BRANTFORD TREATED WATER, 10 BOTTLES NOS. XI - XI0

COLLECTED DEC. 16, 1976

All halomethane values in micrograms per litre

No.	Date	Column	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
DIRECT INJECTION						
XI	Dec. 21	SE-30	86	11.3	1.4	4.2
XI	Jan. 14	TENAX	101	17.5	1.2	<1
XI	Jan. 23	TENAX	110	13.3	1.0	<1
XI	Feb. 9	TENAX	102	12.0	0.9	<1
XI	Feb. 16	TENAX	112	11.0	-	<1
X5	Jan. 14	TENAX	113	20.5	-	-
X7	Jan. 23	TENAX	114	14.3	0.8	<1
X9	Feb. 9	TENAX	112	17.3	0.8	<1
X10	Feb. 10	TENAX	111	13.3	0.7	<1
SPARGE						
XI	Dec. 16	Carbowax	92	10.6	1.1	< 0.1
XI	Jan. 21	TENAX	92	10.7	0.93	0.06
XI	Jan. 31	TENAX	88	12.2	1.1	0.05
XI	Feb. 8	TENAX	95	12.0	1.7	0.05
XI	Feb. 18	TENAX	90	10.0	1.2	0.02
X2	Dec. 24	Carbowax	75	13.0	0.5	0.8
X3	Dec. 28	Carbowax	72	13.2	0.3	0.15
X4	Jan. 4	Carbowax	88	13.4	1.3	0.8
X4	Jan. 4	Carbowax	80	15.2	2.3	2.6
X5	Jan. 17	TENAX	98	11.6	0.91	0.14
X6	Jan. 21	TENAX	86	10.1	0.87	0.04
X8	Jan. 31	TENAX	91	12.8	1.1	0.05
X9	Feb. 8	TENAX	98	12.6	1.8	0.04

TABLE 9: SUMMARY OF STATISTICAL DETERMINATION OF EFFECT OF STORAGE

	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
Slope of Regression Line	0.215	-0.0149	0.0129	-0.0075
Standard Deviation of Slope	±0.016	±0.0187	±0.0052	±0.0038
$t_{calc.}$	2.03	0.767	2.49	1.97
$t_{95\%, Tables}$	2.23	2.23	2.23 (2.76)*	2.23
Residual about Mean	65.12	1.595	0.1849	0.0835
Residual About Regression Line	50.69	1.513	0.1246	0.066
$F = \frac{\text{Residual about Mean}}{\text{Residual about Line}}$	1.28	1.054	1.48	1.26
$F_{95\%, Tables}$	2.95	2.85	2.95	2.95

*$t_{99\%}$

Results and Discussion

The production of halomethanes by the reaction of chlorine with naturally occurring organic compounds present in drinking water is a time dependent reaction. There is, therefore, some question as to where to take samples in the drinking water treatment system and how to handle the samples between the time of sampling and the time of analysis. United States surveys (5, 6) have taken samples at the water treatment plants just prior to the treated water entering the distribution system. The samples were refrigerated but the free chlorine residual was not destroyed. The production of halomethanes could have proceeded, therefore, albeit at a reduced rate. However, it was felt that this additional reaction would represent to some extent the reactions that would have occurred in the distribution system and that the analytical results would be indicative of the halomethane levels to which the consumer would be exposed.

It was felt that in this present survey a better approach was to collect water samples not only at the water treatment plant but also at two points in the distribution system.

In addition, sodium thiosulfate was added to the water samples at the time of collection to remove the free chlorine residual and hence to stop the production of halomethanes. Since the production of halomethanes is a multi-step reaction there were still present, in the samples, intermediates which can break down to give halomethanes. However, these are thermodynamically controlled reactions and were not anticipated to occur under refrigerated conditions. Storage experiments with thiosulfate treated samples under refrigerated conditions (Table 8) indicated that no change in halomethane levels could be detected over a period of nine weeks storage. Ontario studies (7, 8) have indicated that the reaction intermediates will break down when heated and that the levels of halomethanes detected are dependent on the method of analysis. Gas sparging methods of analysis which do not involve heating the water samples give halomethane levels actually present in the water sample. In direct aqueous injection methods of analysis the water samples come in contact with the injection port of the gas chromatograph which is at a high temperature. Breakdown of the intermediates then occurs and the levels of halomethanes may be increased. Nicholson et al (7) have used the term total potential halomethanes to describe the halomethane levels found by the direct aqueous injection method of analysis. Both methods of analysis were used in this present survey in order to determine whether any relationship could be found between the halomethane levels obtained by the two methods of analysis.

Some problems were experienced by the contractor in finding one chromatographic column suitable for both methods of analysis and, therefore, the use of an SE-30 column for the direct injection method and a Carbowax column for the gas sparge method were initially chosen. However, considerable time was being lost by the necessity of changing columns for each method of analysis for each batch of samples. From work carried out at the Health Protection Branch and at the contractors laboratories it was subsequently determined that a Tenax-GC column could be used for both methods of analysis thus removing the necessity to change columns for each method. Consequently, the Tenax column was used by the contractor for the last half of the survey.

Two gas-chromatography detectors have been used by previous workers to detect halomethanes; the electron-capture detector and the Hall conductivity detector. The electron-capture detector is extremely sensitive but is not specific for halogen containing compounds whereas the conductivity detector, operating in the halogen mode, is more specific but has less sensitivity. In this present survey, water samples were analysed with an electron-capture detector by the contractor. In addition one duplicate sample (station 1) from each municipality was analysed by the Health Protection Branch using a Hall conductivity detector operating in the halogen mode.

The full analytical data on halomethane levels in the water samples from the seventy locations sampled is presented in Appendix 2. A summary of this data is given in Tables 10, 11, 12 and Figure 1, and is also given as frequency distribution graphs in Appendix 4.

The analytical data obtained by the Health Protection Branch are given in Appendix 2, and summarised in Table 13. Halomethane levels measured in the raw water were either not detected or were present at very low concentrations.

TABLE 10: HALOMETHANE LEVELS IN TREATED WATER

Compound	Methods of Analysis	LEVELS (µg/ℓ) Range	Mean	Median
Chloroform	Gas Sparge	0-77	18.4	8.0
	Direct Injection	0-144	24.0	9.9
Bromodichloro-methane	Gas Sparge	0-23	2.0	0.8
	Direct Injection	0-29	2.2	0.7
Chlorodibromo-methane	Gas Sparge	0-4.6	0.3	0.1
	Direct Injection	0-5.8	0.3	-
Bromoform	Gas Sparge	0-1.5	0.1	-
	Direct Injection	-		

Comparison of the results in Table 11 and Table 13 indicate that agreement between the average sparge values for the contractors and Health Protection Branch results are good for chloroform but that the Health Protection Branch values for bromodichloromethane and chlorodibromomethane are somewhat lower. Graphical comparisons of analytical data for $CHCl_3$ and $CHCl_2Br$ on duplicate samples are presented in Figures 2 and 3. The concentrations of both compounds as determined using an electron capture detector are higher than those determined using a Hall microcoulometric detector. The relative difference is greater at low concentrations possibly resulting from differences in sensitivity of the detectors. The Hall detector is known to be less sensitive than the electron capture detector for this application. The scatter of the data at the low concentrations is probably the result of the relatively poor precision at these concentrations.

TABLE 11: HALOMETHANE LEVELS IN DISTRIBUTION SYSTEM

STATION 1

Compound	Methods of Analysis	LEVELS (µg/ℓ) Range	Mean	Median
Chloroform	Gas Sparge	0-121	22.7	13.0
	Direct Injection	0-150	30.8	16.0
Bromodichloro-methane	Gas Sparge	0-33	2.9	1.4
	Direct Injection	0-44	3.1	1.3
Chlorodibromo-methane	Gas Sparge	0-6.2	0.4	0.1
	Direct Injection	0-7.0	0.4	-
Bromoform	Gas Sparge	0-1.0	0.1	-
	Direct Injection	-	-	-

TABLE 12: HALOMETHANE LEVELS IN DISTRIBUTION SYSTEM

STATION 2

Compound	Methods of Analysis	LEVELS (µg/ℓ) Range	Mean	Median
Chloroform	Gas Sparge	0-85	24.5	13.5
	Direct Injection	0-122	32.1	18.5
Bromodichloro-methane	Gas Sparge	0-27	2.6	1.3
	Direct Injection	0-22	2.7	1.6
Chlorodibromo-methane	Gas Sparge	0-4.9	0.4	0.1
	Direct Injection	0-4.5	0.4	-
Bromoform	Gas Sparge	0-2.1	0.1	-
	Direct Injection	-	-	-

TABLE 13: HALOMETHANE LEVELS IN DISTRIBUTION SYSTEM

STATION 1 GAS SPARGE DATA (NHW)

Compound	LEVELS (µg/ℓ) Range	Mean	Median
Chloroform	0-83	21.6	9.0
Bromodichloromethane	0-15	1.93	1.0
Chlorodibromomethane	0-6.5	0.26	-
Bromoform	N.D.	--	--

Comparison of Gas Sparging and Direct Injection Analysis

The results from the two techniques are compared in terms of total trihalomethane (TTHM) concentrations (micro-moles per litre) for raw, treated, and distribution system water samples in Figures 4, 5, 6 and 7 respectively. Equations for the lines of best fit and their correlation coefficients are presented for the treated water and station 1 and 2 samples. Similar slopes indicate a consistent relationship between direct injection and sparged techniques. The relationship for raw water is poorly defined, as only low concentrations of trihalomethanes were found in the raw water.

In Figures 8 and 9 the data obtained for chloroform and bromodichloromethane in treated water have been fitted with linear least square lines of best fit.

For all of these comparisons the average sparge value is consistently 70-75% of the direct injection value. However, it should be noted that despite the excellent correlation coefficients there is still significant variation in the ratio of gas sparging results to direct injection results on a station to station basis.

Effects of Raw Water Quality

Source

Raw water for municipal water systems surveyed was obtained from one of three sources; rivers, lakes and wells. In the survey, 39 river sources, 20 lake sources and 11 well sources were sampled. Figures 10, 11 and 12 show the frequency distributions of sparged TTHM in the treated water from river, lake and well sources respectively. The distribution

of halomethanes in treated water from river and lake sources is similar with median values of 0.096 μ moles/ℓ and 0.086 μ moles/ℓ respectively and mean values of 0.20 and 0.21 μ moles/ℓ respectively. The median and mean values of sparged TTHM in treated water from well sources is significantly lower at 0.018 μ moles/ℓ and 0.023 μ moles/ℓ.

Total Organic Carbon

The dependence of halomethane concentrations in treated waters on the total organic carbon (TOC) content of the raw water supply was demonstrated by Symons et al (5). In this survey the TOC of all samples was measured to provide a data base for a similar comparison for Canadian municipalities. The frequency distribution of the TOC content of the raw water samples is shown in Figure 13. The median value for the TOC distribution is 4.0 mg/ℓ for this survey.

The relationship between total trihalomethanes (TTHM) in treated water and raw water TOC is illustrated in Figure 14 for individual paired data. By grouping the data into TOC ranges, a technique employed by Symons et al, the correlation is apparently improved significantly as illustrated in Figure 15.

pH and Hardness

As shown in Figures 16 and 17, no discernible correlation between TTHM levels in treated water and pH or hardness of raw water can be established.

Effects of Water Treatment Practices

Chlorination

The practice of disinfecting drinking water by chlorination produces measurable quantities of trihalomethanes in the treated water. Data on the application rates of chlorine for drinking water disinfection were collected during the survey to determine the effect on the measured concentrations of total trihalomethanes (TTHM). TTHM concentration as determined by gas sparging is presented as a function of chlorine dosage in Figure 18, and as a function of chlorine residual in Figure 19. A weak correlation is apparent between TTHM concentration and chlorine dosage, and no correlation is apparent with chlorine residual.

Chlorine demand obtained by subtracting chlorine residual from the chlorine dosage gives a weak correlation as indicated in Figure 20. Grouping the data as was done by Symons et al (5) apparently strengthens the correlation.

Figure 21 presents the least squares line of best fit for the data.

Persistence of Halomethanes in Water Distribution Systems

In the survey, samples of the treated water were collected immediately after treatment, and at two stations on the water distribution system within a half mile of the water treatment plant. The purpose of this procedure was to determine if there was any change, either an increase or decrease, in the concentration of halomethanes in the drinking water supply between the time of treatment and the time of use.

Using paired data from each municipality and calculating the mean difference of all the paired data, the TTHM concentrations by gas sparging at the two distribution system sampling stations were compared using a "t" test. No significant difference between these two points was found at the 95% confidence level.

As there was no significant difference between Stations 1 and 2, an average TTHM value could be calculated for the distribution system at each municipality. Then the mean difference between the TTHM concentration in the distribution system and the treated water was calculated and compared to zero using a "t" test. At the 95% confidence level, the TTHM concentrations in the distribution system were found to be significantly higher than in the treated water as shown in Table 14 below.

TABLE 14: COMPARISON OF MEAN CONCENTRATION OF TTHM IN TREATED WATER AND DISTRIBUTION SYSTEM USING PAIRED DATA

	Treated Water	STATION 1	STATION 2
TTHM (μ moles/ℓ)	0.173	0.212	0.211

Actual frequency distributions for the various halomethane concentrations in water from these stations are included in Appendix 4.

Other Water Treatment Practices

A relatively small number of water treatment plants across Canada use activated carbon; ammoniation for preservation of chlorine residual in the distribution system, $KMnO_4$ for taste and odour control, or ozonation to supplement addition of chlorine. As only a small number of treatment plants sampled practice each type of treatment (5 activated carbon,

8 ammonia, 6 ozone, 6 $KMNO_4$) the results of any statistical analysis of these data would be suspect.

Figures 22 to 26 show the frequency distribution of TTHM as measured by the gas sparging technique in treated waters for plants using activated carbon, ammonia, ozone and $KMnO_4$ treatment respectively, in addition to chlorination.

These distributions do not appear to differ significantly from those for lakes and rivers in Figures 10 and 11 which are representative of the overall TTHM distribution.

Conclusions and Preliminary Health Effects Assessment

This survey has given an overview of the halomethane levels occurring in Canadian drinking waters during the winter months. Since the halomethane data is generated from samples taken at only one point in time, for each municipality, the halomethane levels reported should not be considered as absolute values but should be taken as representative of halomethane values for these municipalities. Halomethane levels in drinking water will show some variation throughout the year as changes occur in raw water flow, raw water quality and water treatment procedures. Correlations have been shown in this survey between halomethane levels and raw water source, raw water total organic carbon, chlorine demand and chlorine dosage.

It is not possible at this time to make a definitive statement on possible health hazards which might be associated with the presence of halomethanes in drinking water.

The feeding of massive doses of chloroform has produced tumors in rodents but, at more realistic doses, chloroform did not prove to be carcinogenic in mice or dogs. The available epidemiological information, although limited, fails to indicate that chloroform is carcinogenic to humans either by occupational or environmental exposures.

Therefore, on the basis of our present knowledge, it cannot be concluded that the consumption of water, containing the levels of halomethanes found in this present survey, represents a health hazard. Further epidemiological studies are in progress and, when completed, will be reviewed together with animal toxicity data. The potential health hazards which might be associated with halomethanes in drinking water will be reassessed when this additional information is available.

ACKNOWLEDGEMENTS

This study was carried out by IEC International Environmental Consultants Ltd., Islington, Ontario and was funded by National Health and Welfare, Canada through the Department of Supply and Services under contracts OSW76-00313 and OSZ77-00026.

The scientific authority for these contracts was Dr. D.T. Williams. This directorate report is a combined, edited version of the two IEC contract reports describing the sampling program, analytical results, and subsequent statistical data analysis, augmented by additional details of those analyses carried out by Health and Welfare, Canada.

Halomethane analyses were carried out by Dr. A.H. Debnam, Technical Services Laboratories, and by R. Otson and P. Bothwell, Health and Welfare, Canada. Total organic carbon analyses were performed by the Institute for Environmental Studies, University of Toronto.

Health and Welfare, Canada wished to thank the representatives of each municipality for providing willing assistance to the field technologists and for completing the water treatment practices questionnaires.

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6. Preliminary Assessment of Suspected Carcinogens in Drinking Water - Report to Congress. Washington, D.C., December 1975.
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FIGURE 1

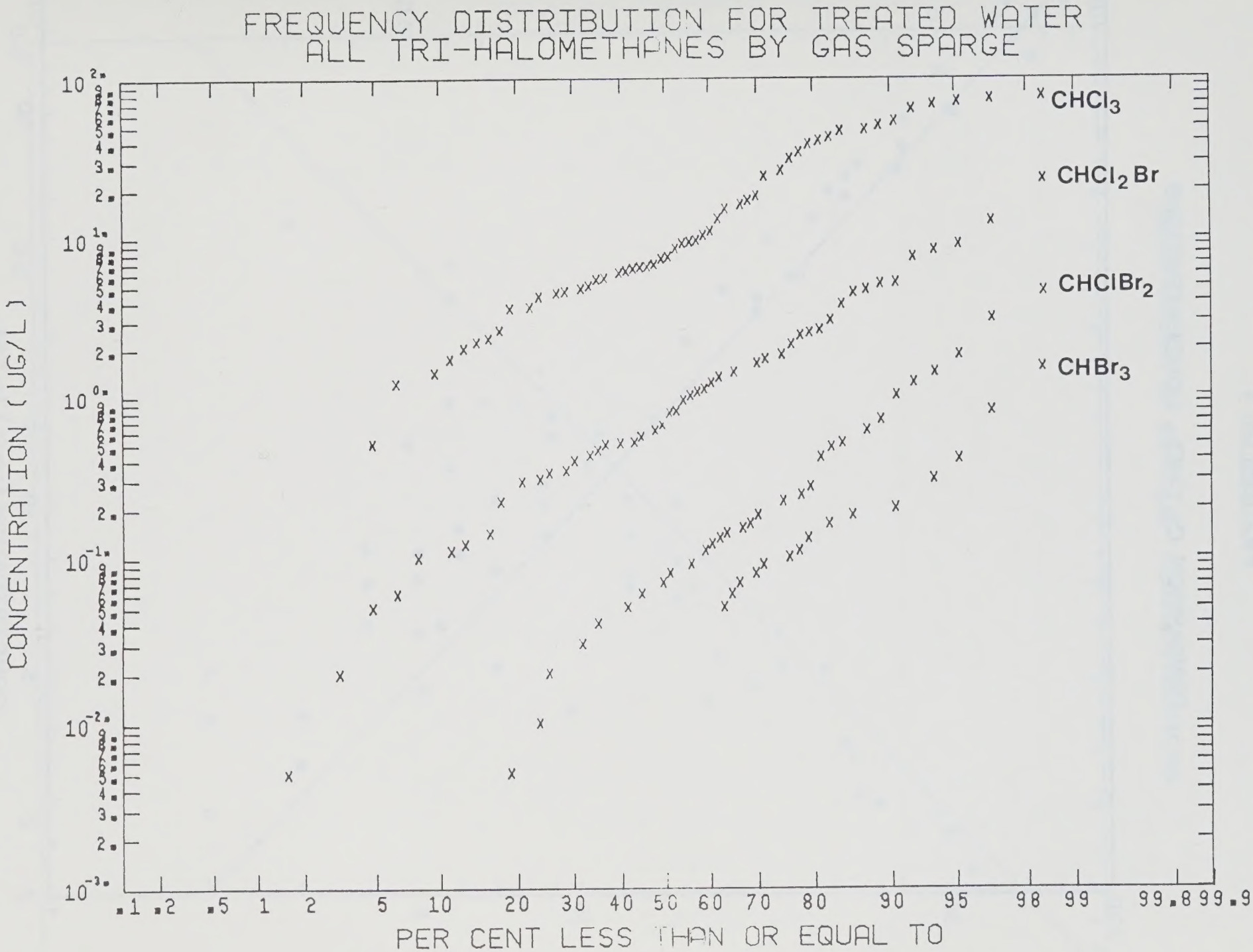

FREQUENCY DISTRIBUTION FOR TREATED WATER
ALL TRI-HALOMETHANES BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
CHCl3
CHCl2Br
CHClBr2
CHBr3

FIGURE 2

COMPARISON OF $CHCL_3$ CONCENTRATIONS

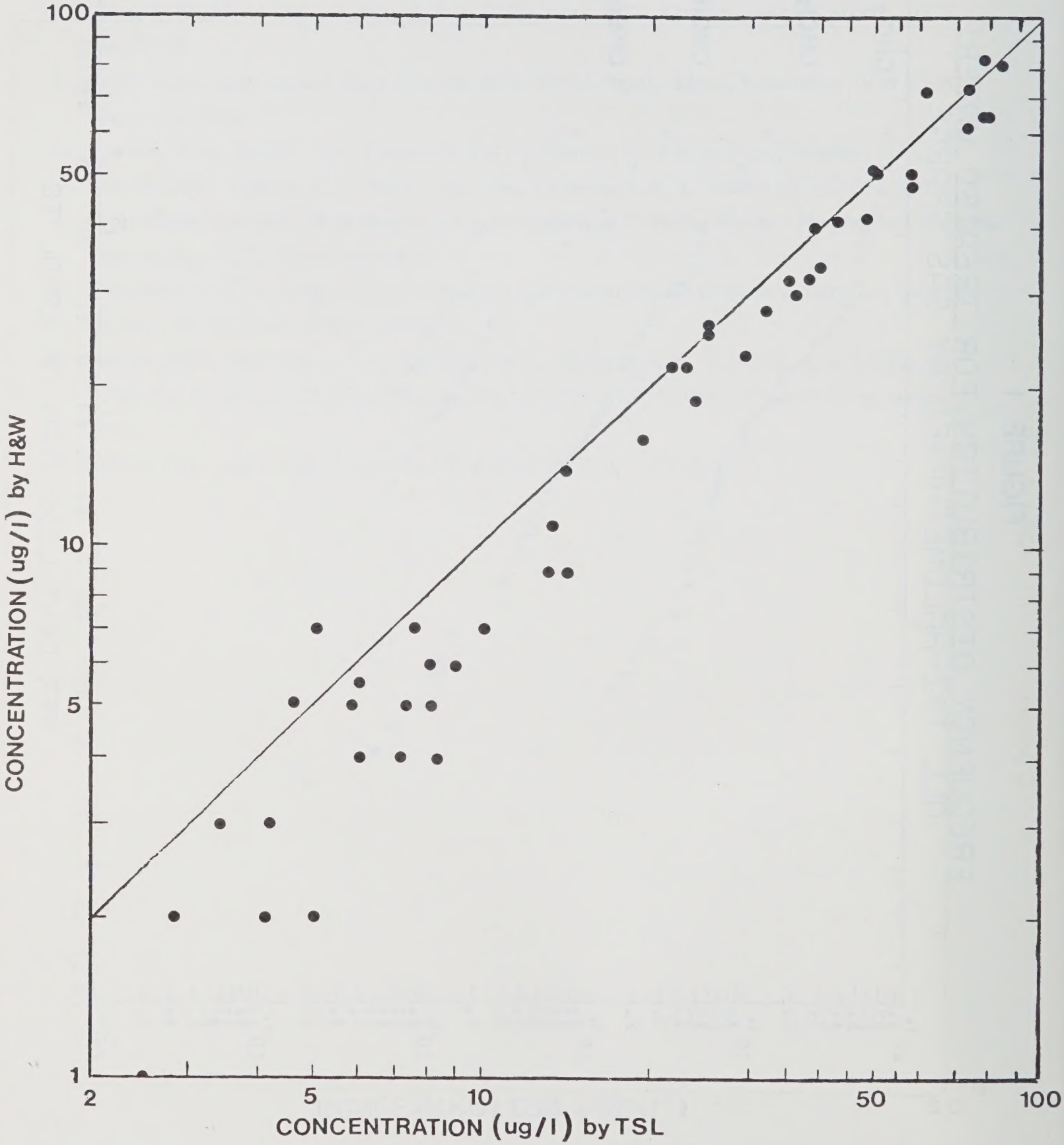


FIGURE 3

COMPARISON OF $CHCL_2Br$ CONCENTRATIONS

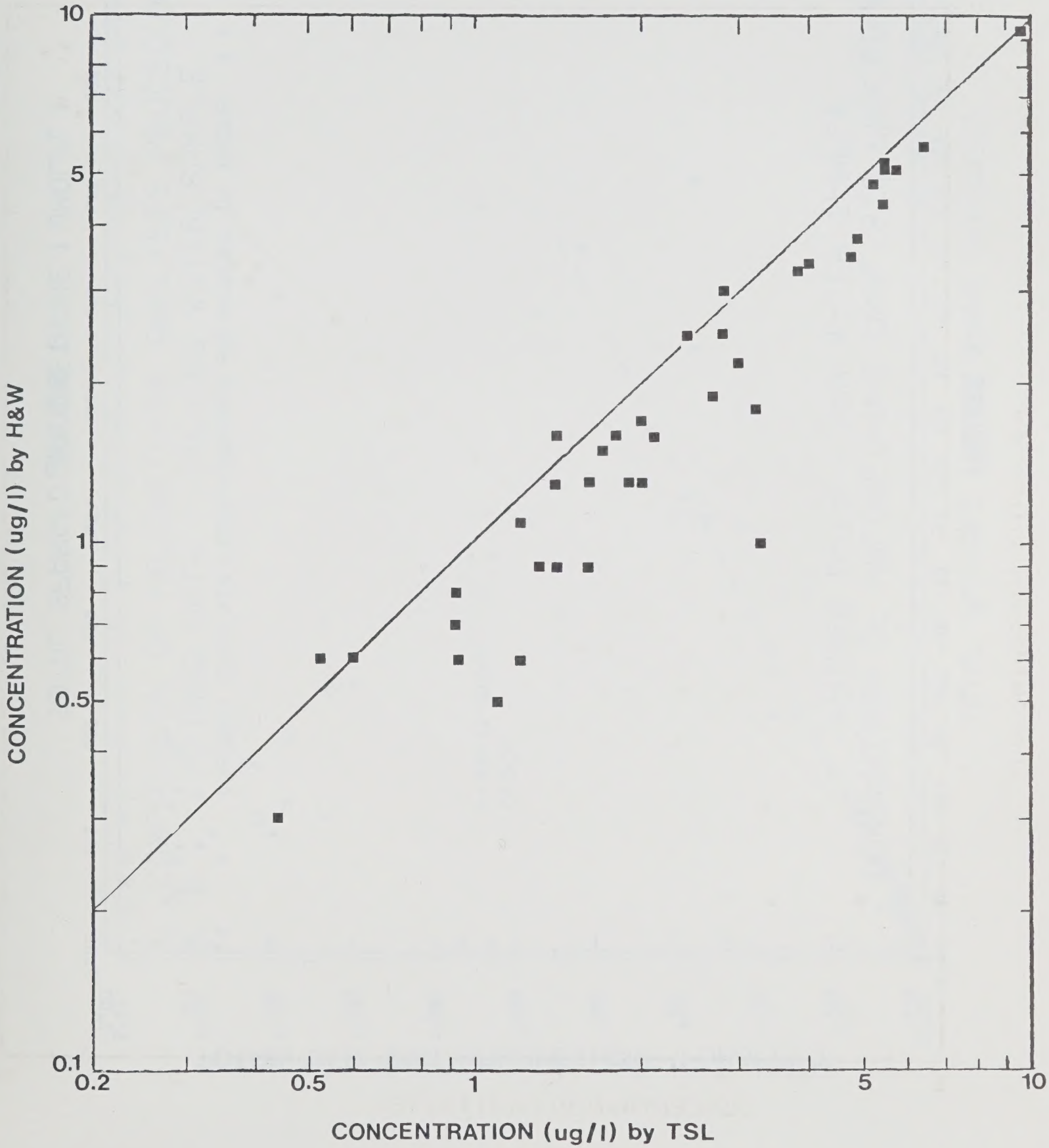


FIGURE 4

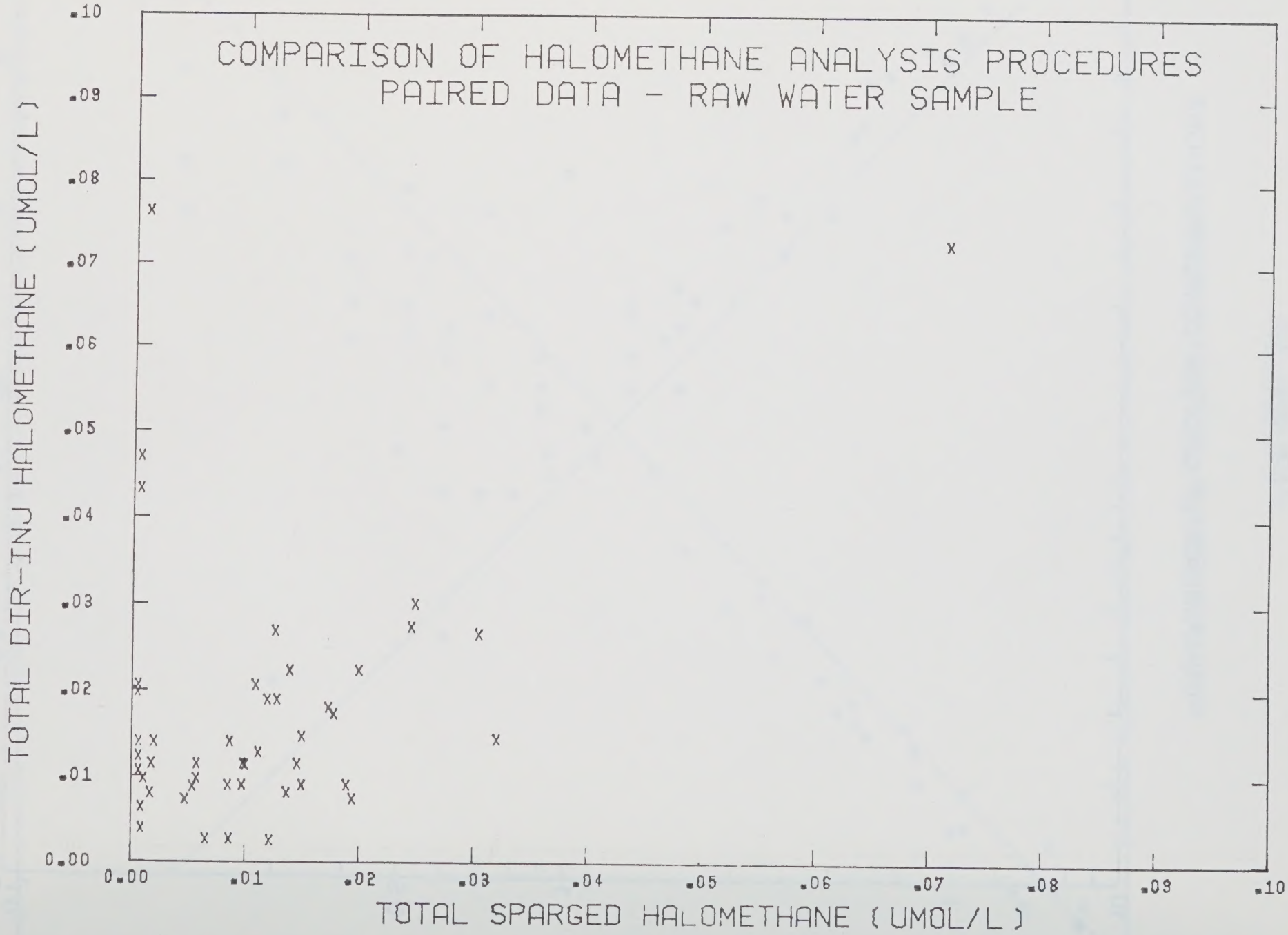

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - RAW WATER SAMPLE
TOTAL DIR-INJ HALOMETHANE (UMOL/L)
TOTAL SPARGED HALOMETHANE (UMOL/L)
0.00
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10

FIGURE 5

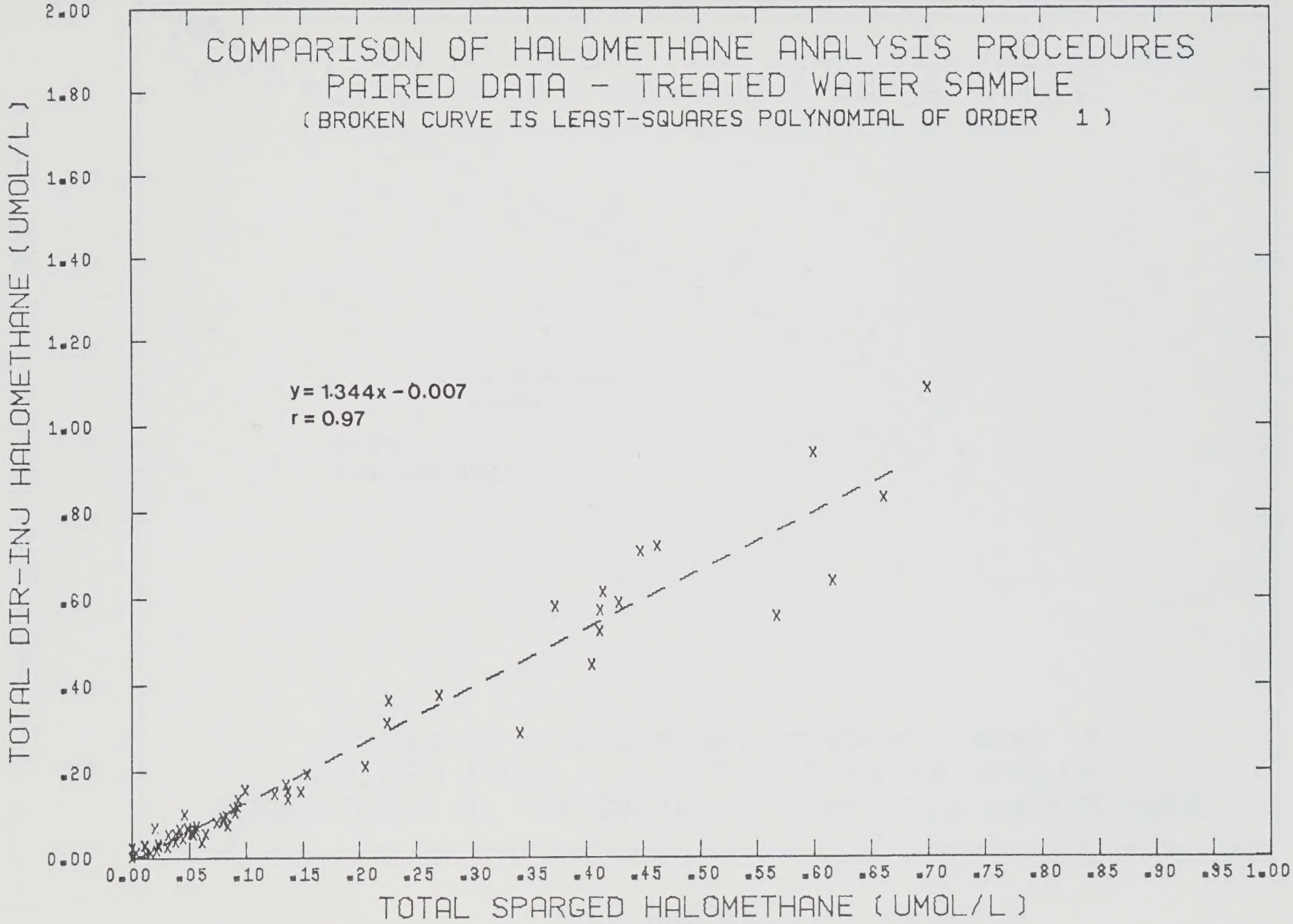

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - TREATED WATER SAMPLE
(BROKEN CURVE IS LEAST-SQUARES POLYNOMIAL OF ORDER 1)
y = 1.344x - 0.007
r = 0.97
TOTAL DIR-INJ HALOMETHANE (UMOL/L)
TOTAL SPARGED HALOMETHANE (UMOL/L)
0.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
0.00 .05 .10 .15 .20 .25 .30 .35 .40 .45 .50 .55 .60 .65 .70 .75 .80 .85 .90 .95 1.00

FIGURE 6

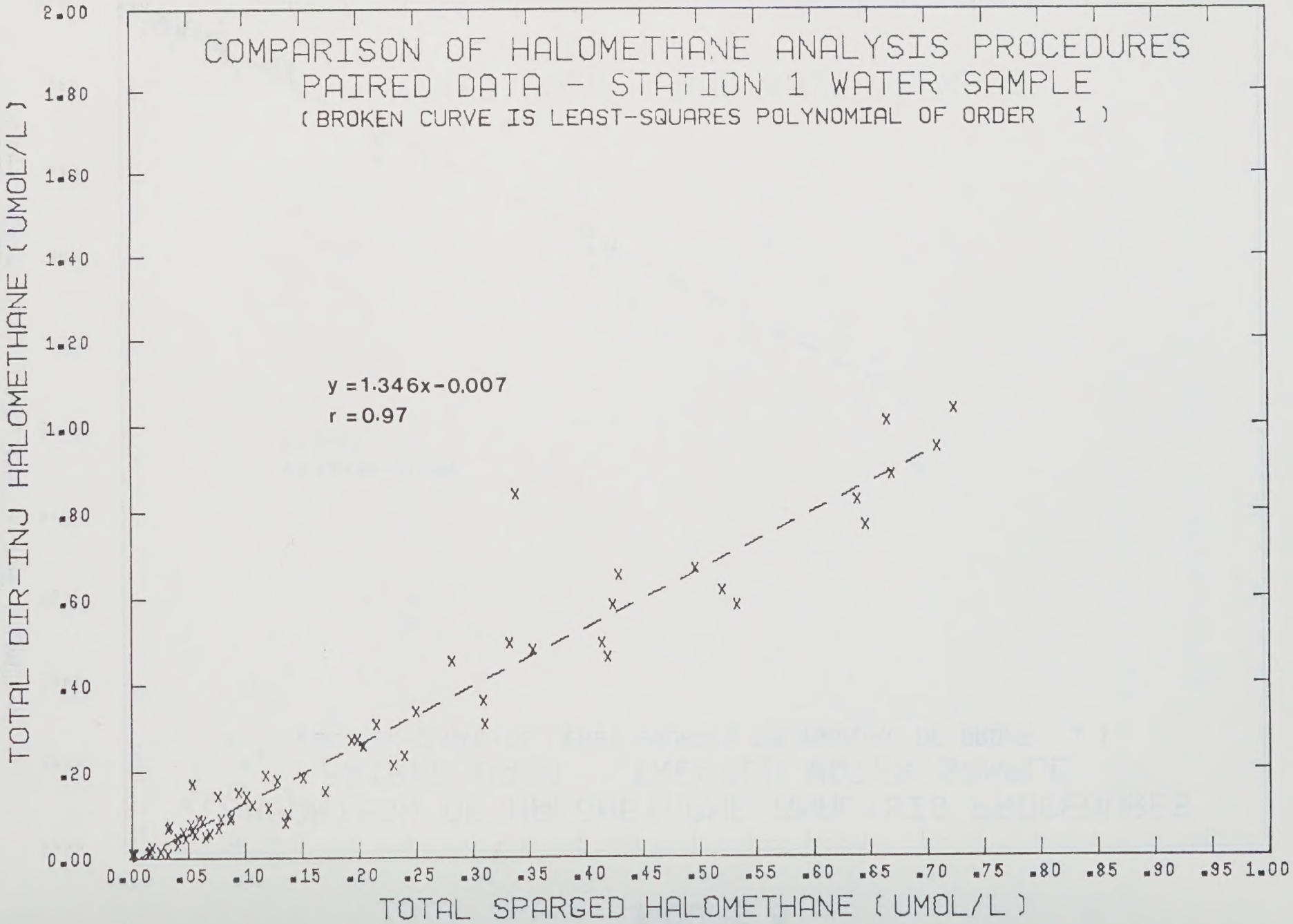

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - STATION 1 WATER SAMPLE
(BROKEN CURVE IS LEAST-SQUARES POLYNOMIAL OF ORDER 1)
y = 1.346x - 0.007
r = 0.97
TOTAL DIR-INJ HALOMETHANE (UMOL/L)
TOTAL SPARGED HALOMETHANE (UMOL/L)
0.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
0.00
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
.55
.60
.65
.70
.75
.80
.85
.90
.95
1.00

FIGURE 7

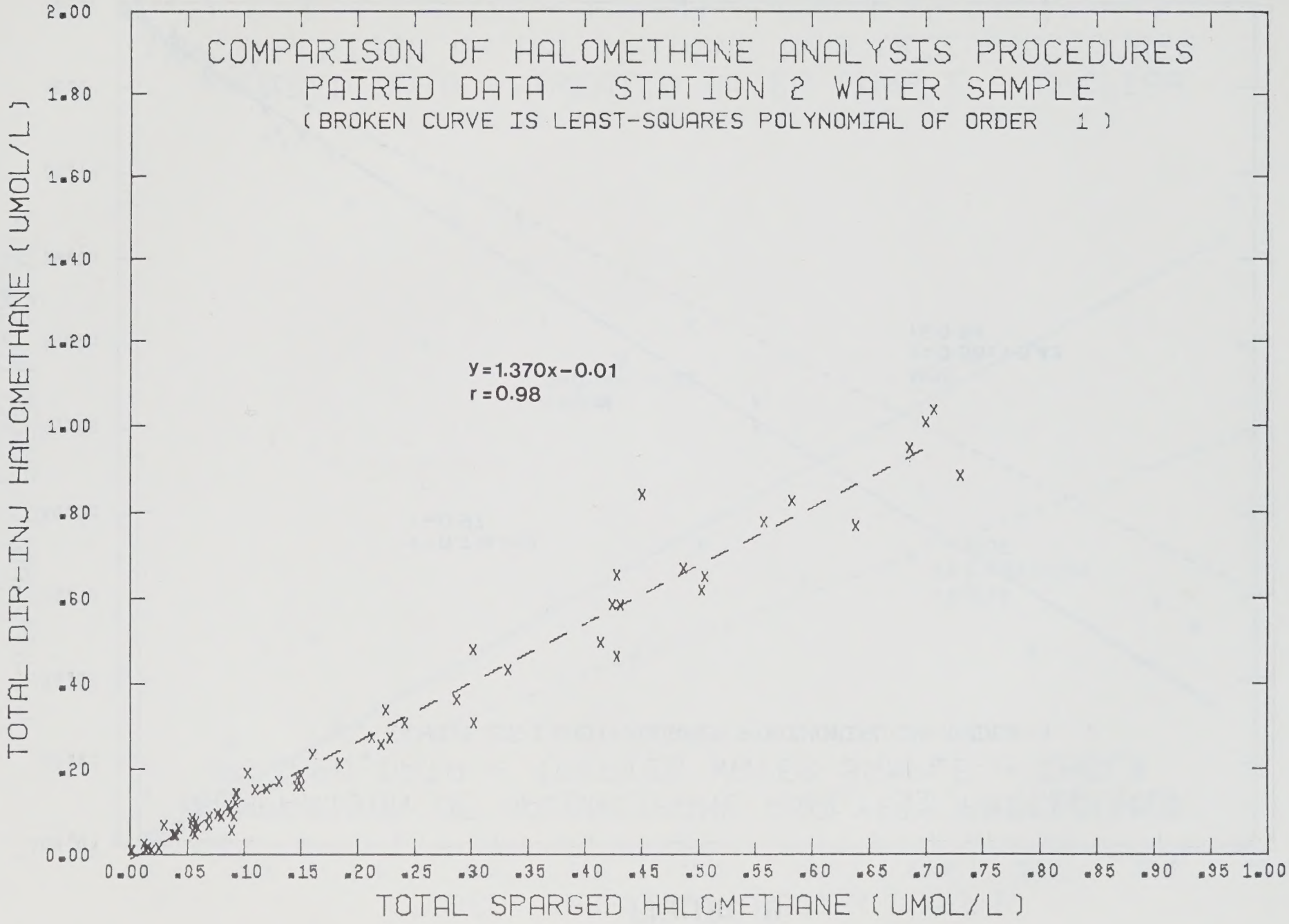

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - STATION 2 WATER SAMPLE
(BROKEN CURVE IS LEAST-SQUARES POLYNOMIAL OF ORDER 1)
y=1.370x-0.01
r=0.98
TOTAL DIR-INJ HALOMETHANE (UMOL/L)
TOTAL SPARGED HALOMETHANE (UMOL/L)
0.00
.20
.40
.60
.80
1.00
1.20
1.40
1.60
1.80
2.00
0.00
.05
.10
.15
.20
.25
.30
.35
.40
.45
.50
.55
.60
.65
.70
.75
.80
.85
.90
.95
1.00

FIGURE 8

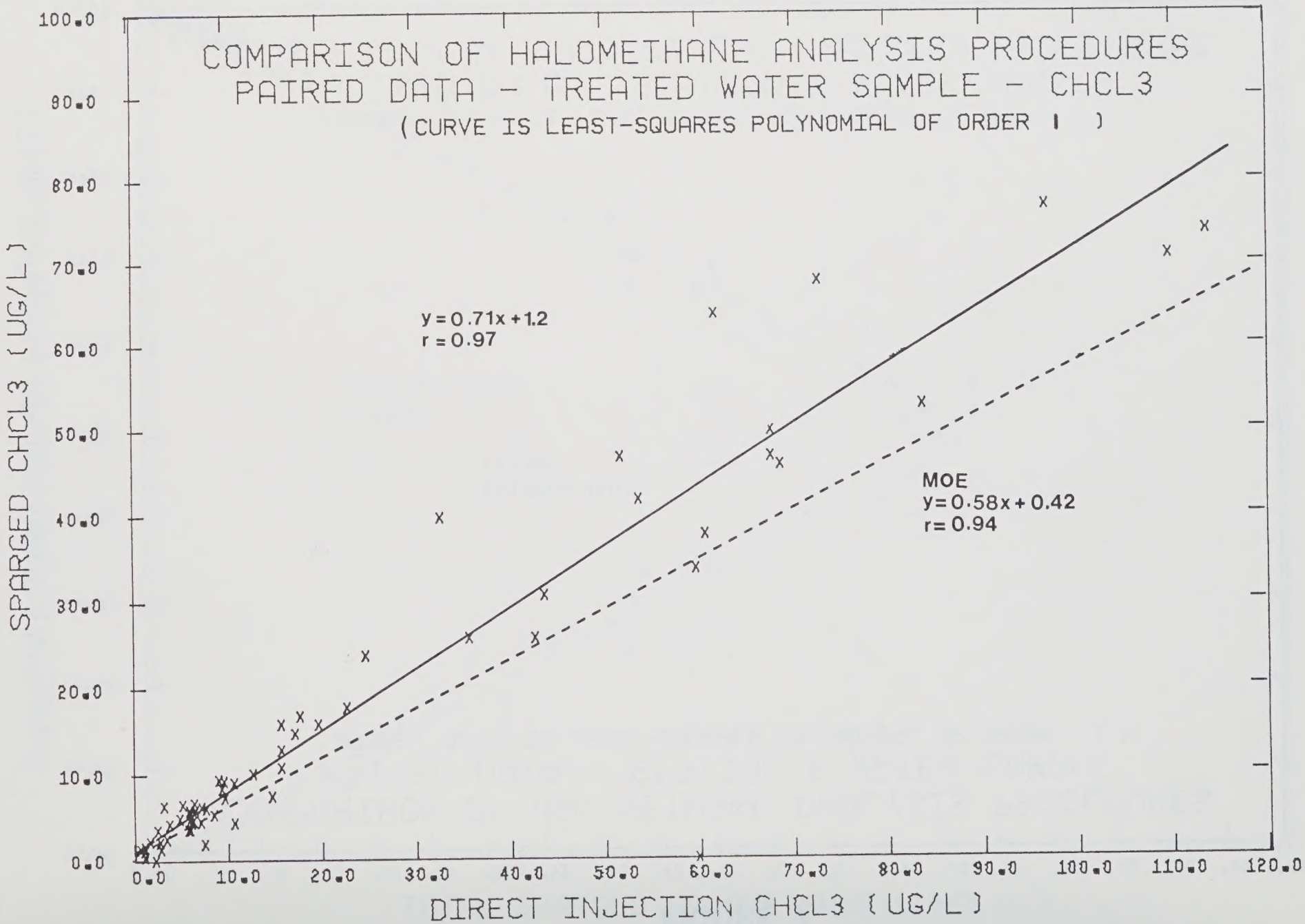

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - TREATED WATER SAMPLE - CHCL3
(CURVE IS LEAST-SQUARES POLYNOMIAL OF ORDER 1)
y = 0.71x + 1.2
r = 0.97
MOE
y = 0.58x + 0.42
r = 0.94
SPARGED CHCL3 (UG/L)
DIRECT INJECTION CHCL3 (UG/L)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0

FIGURE 9

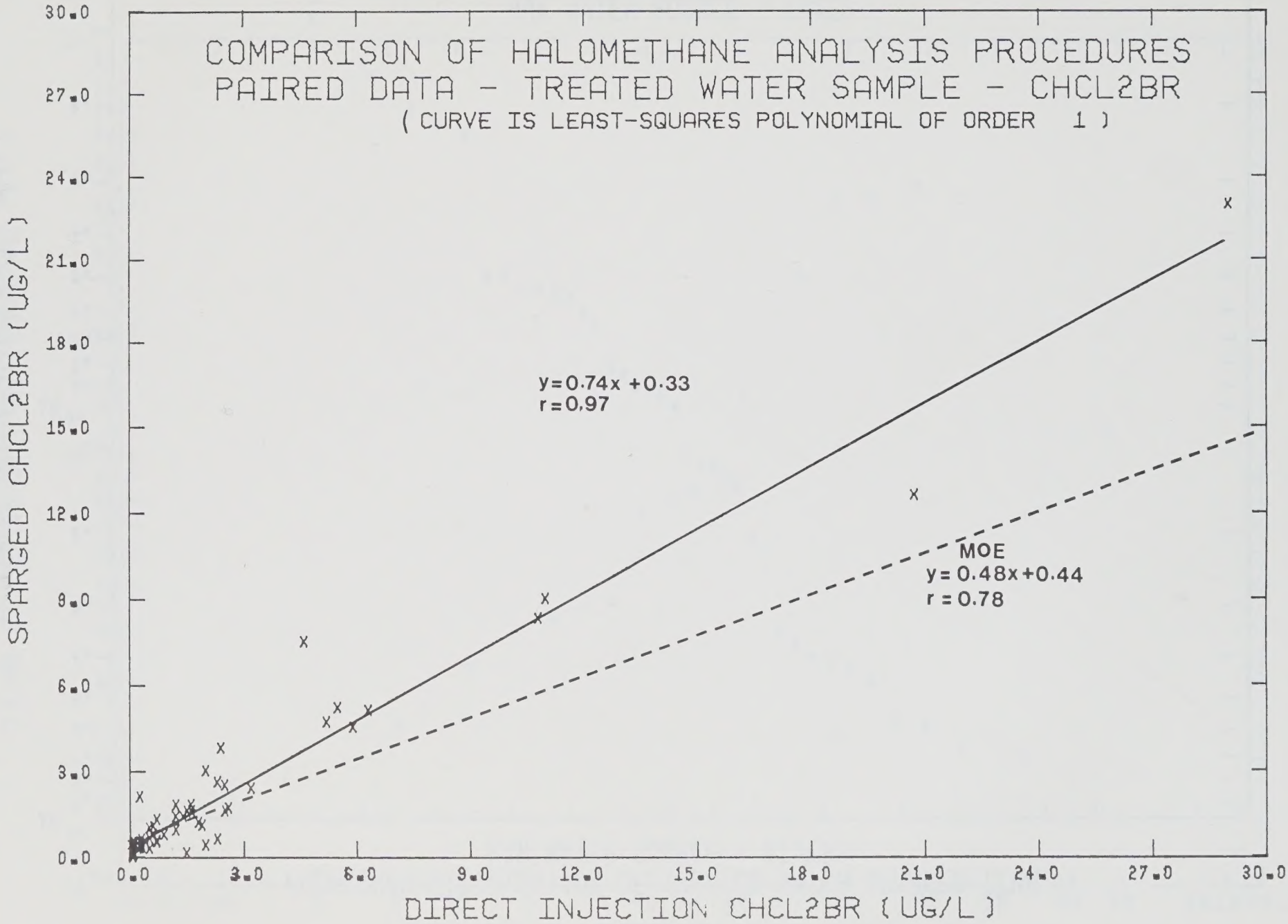

COMPARISON OF HALOMETHANE ANALYSIS PROCEDURES
PAIRED DATA - TREATED WATER SAMPLE - CHCL2BR
(CURVE IS LEAST-SQUARES POLYNOMIAL OF ORDER 1)
y=0.74x +0.33
r=0.97
MOE
y= 0.48x+0.44
r = 0.78
SPARGED CHCL2BR (UG/L)
DIRECT INJECTION CHCL2BR (UG/L)
0.0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0
30.0

FIGURE 10

FREQUENCY DISTRIBUTION OF TREATED WATER SPARGED TTHM
RAW WATER SOURCE - RIVERS

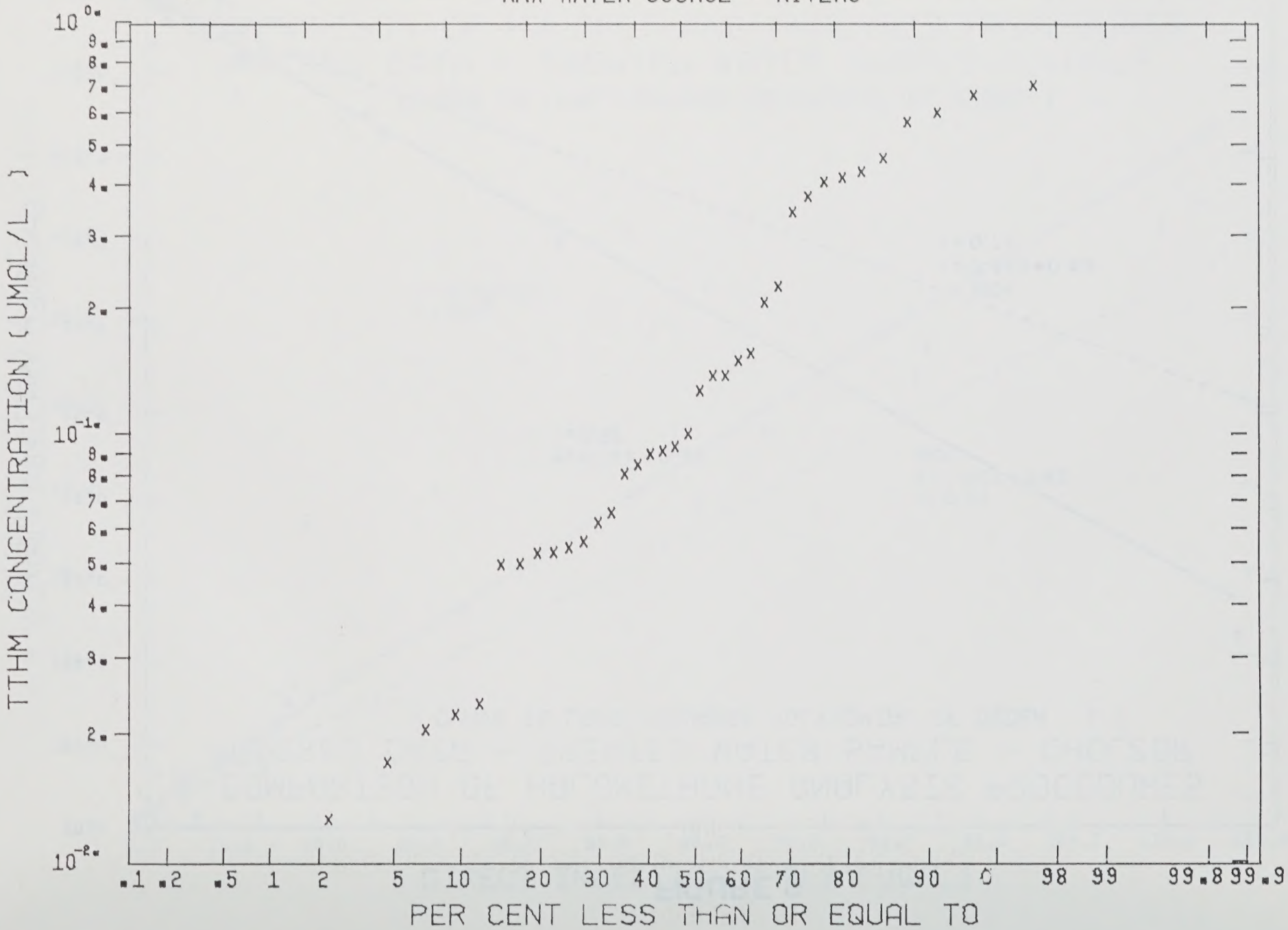


FIGURE 11

FREQUENCY DISTRIBUTION OF TREATED WATER SPARGED TTHM
RAW WATER SOURCE - LAKES

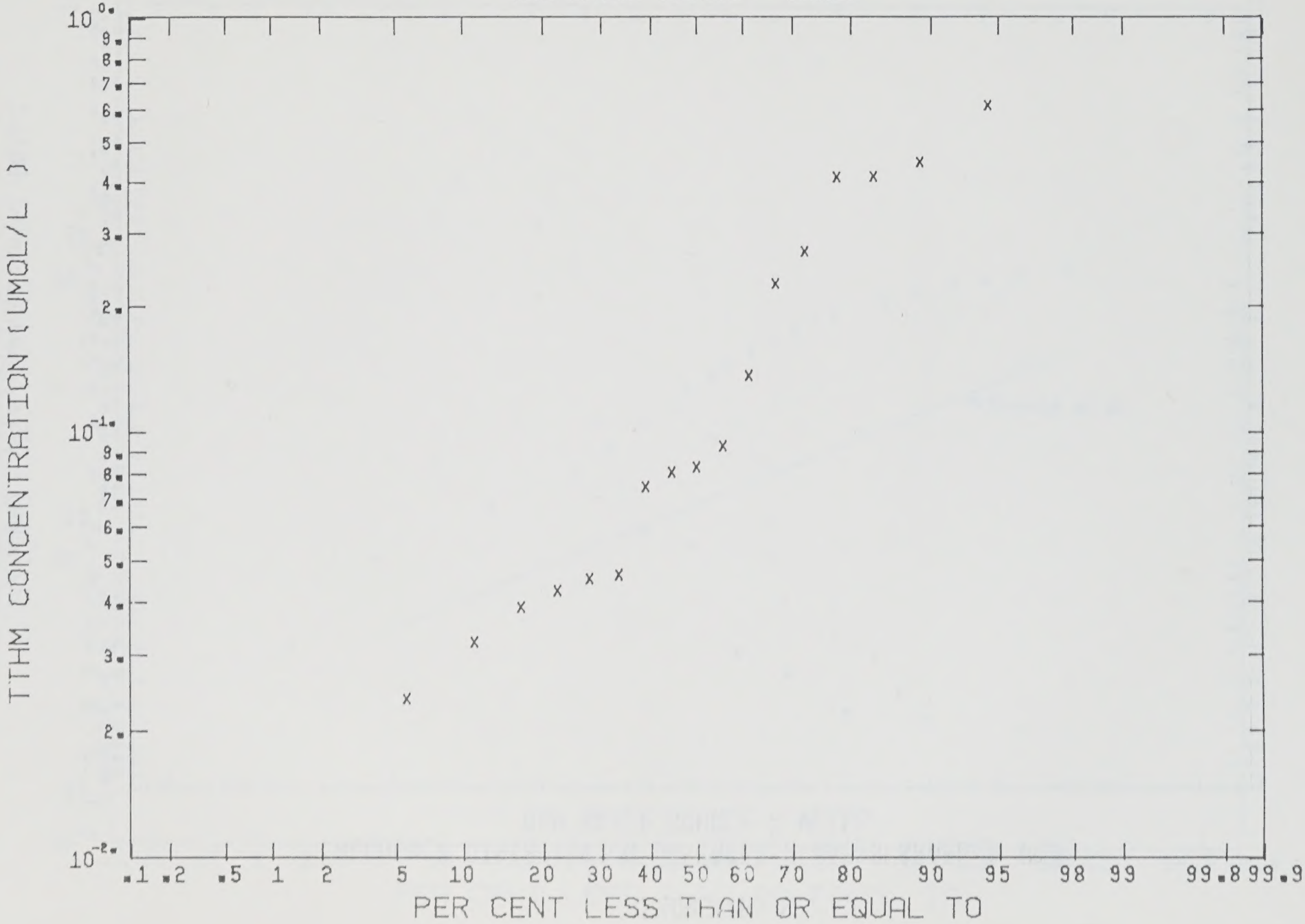


FIGURE 12

FREQUENCY DISTRIBUTION OF TREATED WATER SPARGED TTHM
RAW WATER SOURCE - WELLS

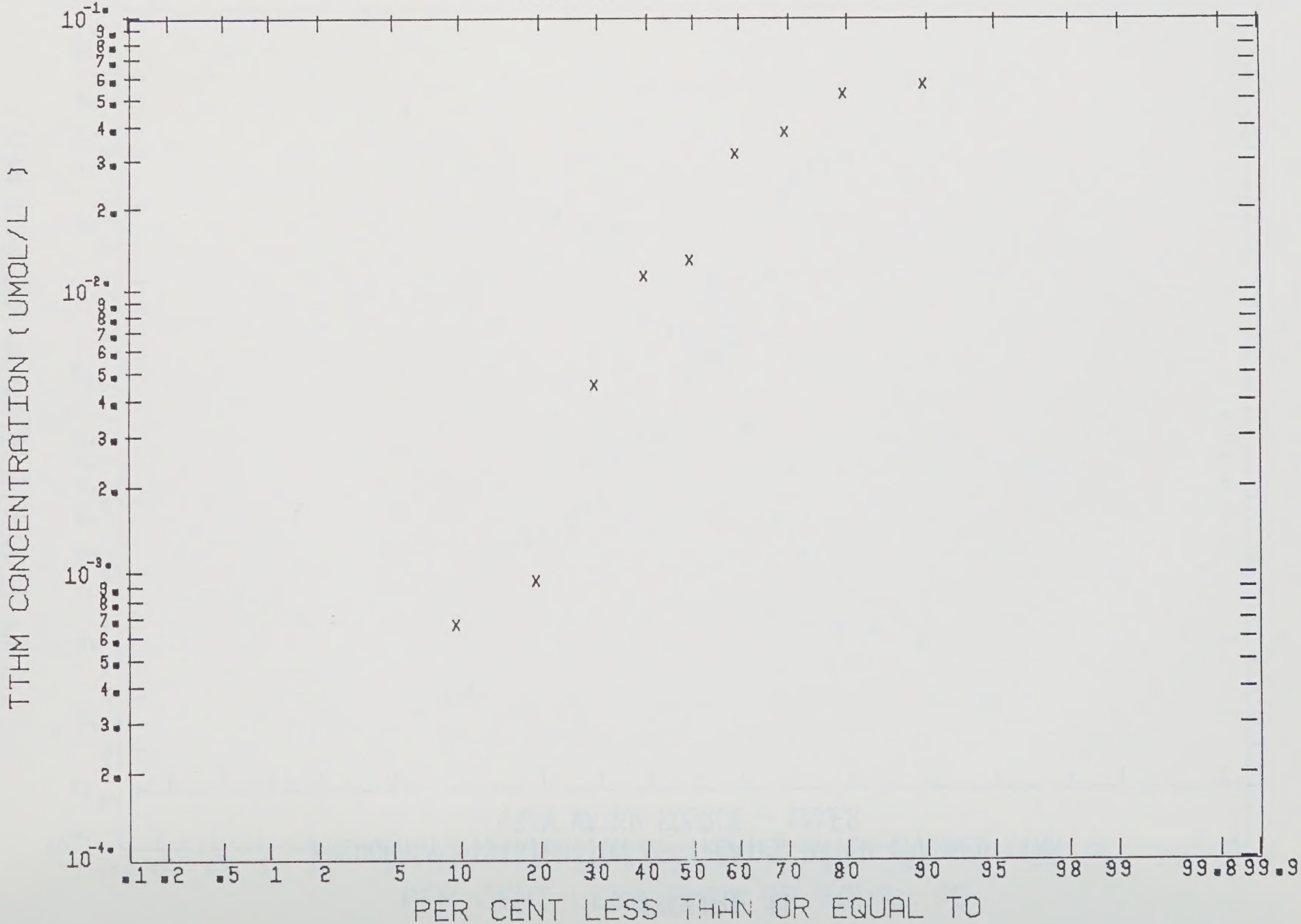


FIGURE 13

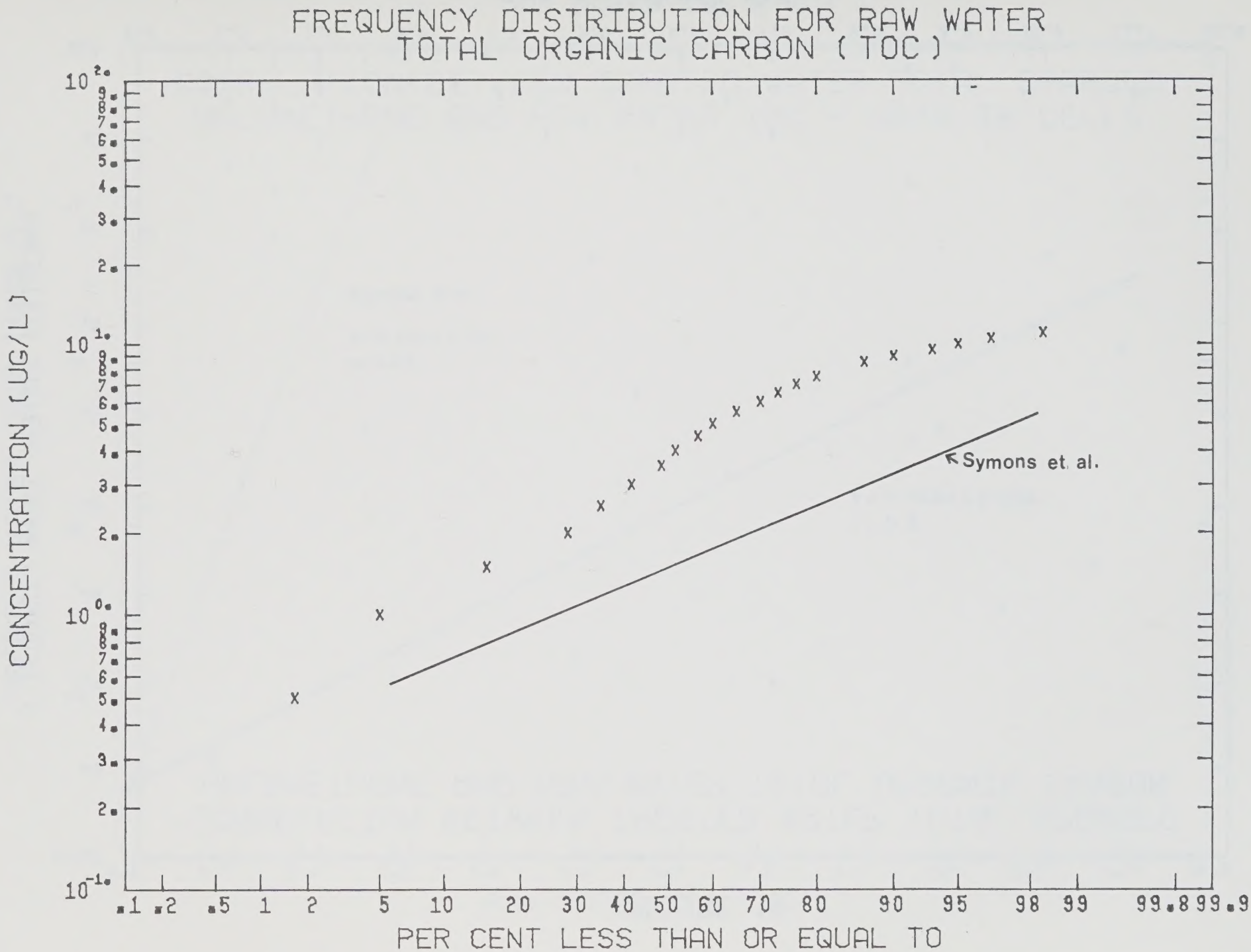

FREQUENCY DISTRIBUTION FOR RAW WATER
TOTAL ORGANIC CARBON (TOC)
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
Symons et. al.

FIGURE 14

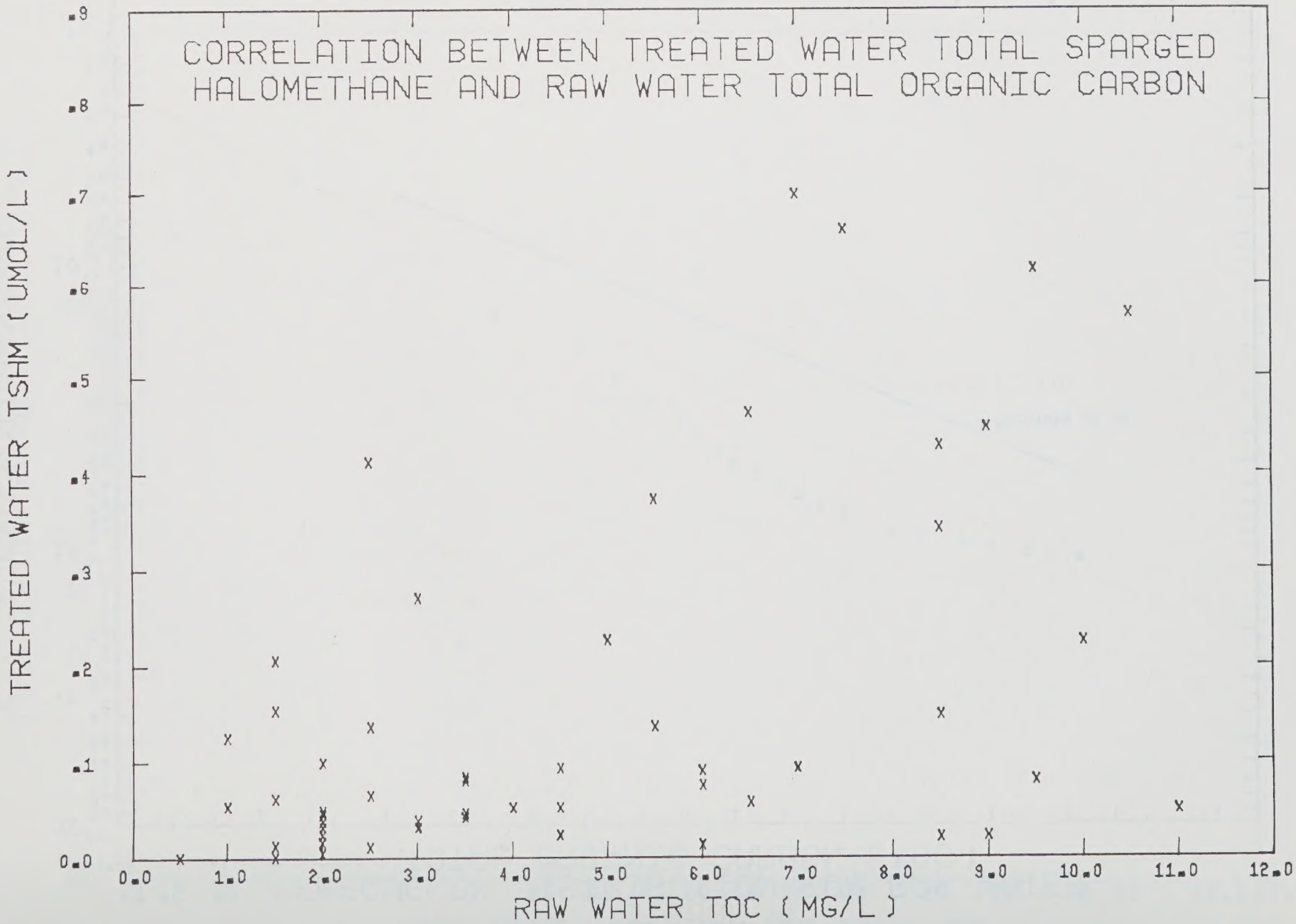

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND RAW WATER TOTAL ORGANIC CARBON
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
RAW WATER TOC (MG/L)

FIGURE 15

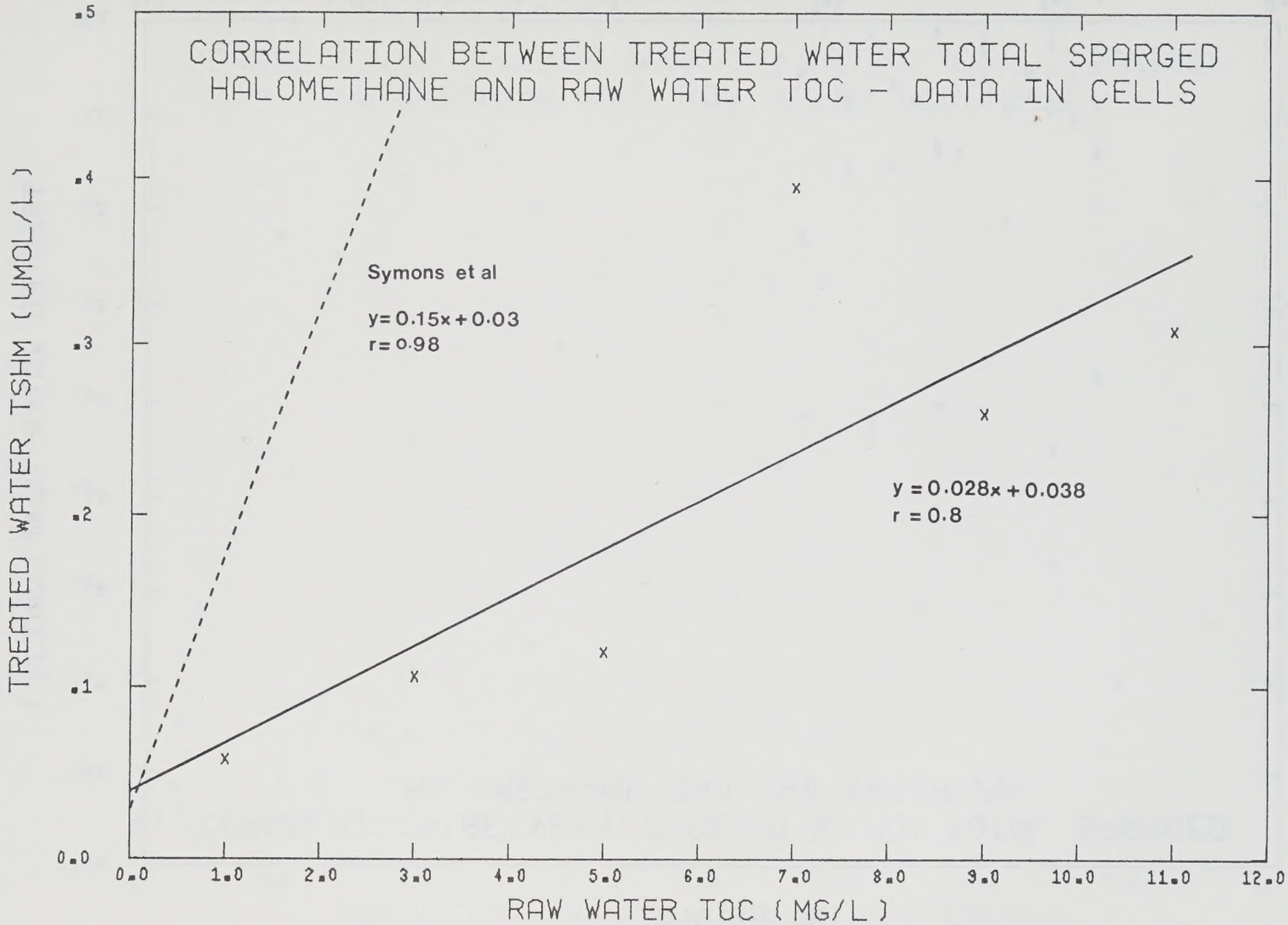

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND RAW WATER TOC - DATA IN CELLS
Symons et al
y= 0.15x + 0.03
r= 0.98
y = 0.028x + 0.038
r = 0.8
TREATED WATER TSHM (UMOL/L)
RAW WATER TOC (MG/L)
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

FIGURE 16

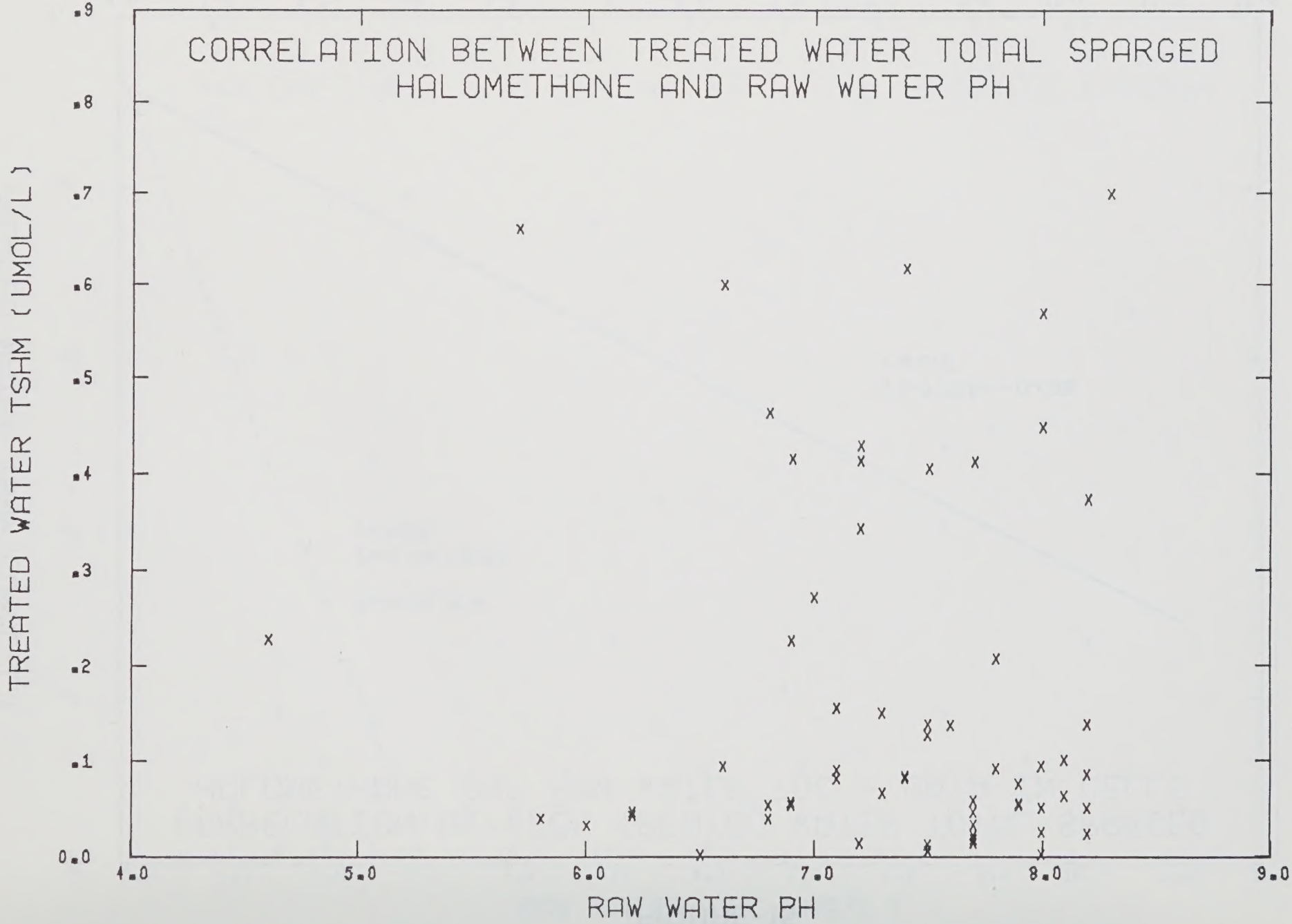

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND RAW WATER PH
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
4.0
5.0
6.0
7.0
8.0
9.0
RAW WATER PH

FIGURE 17

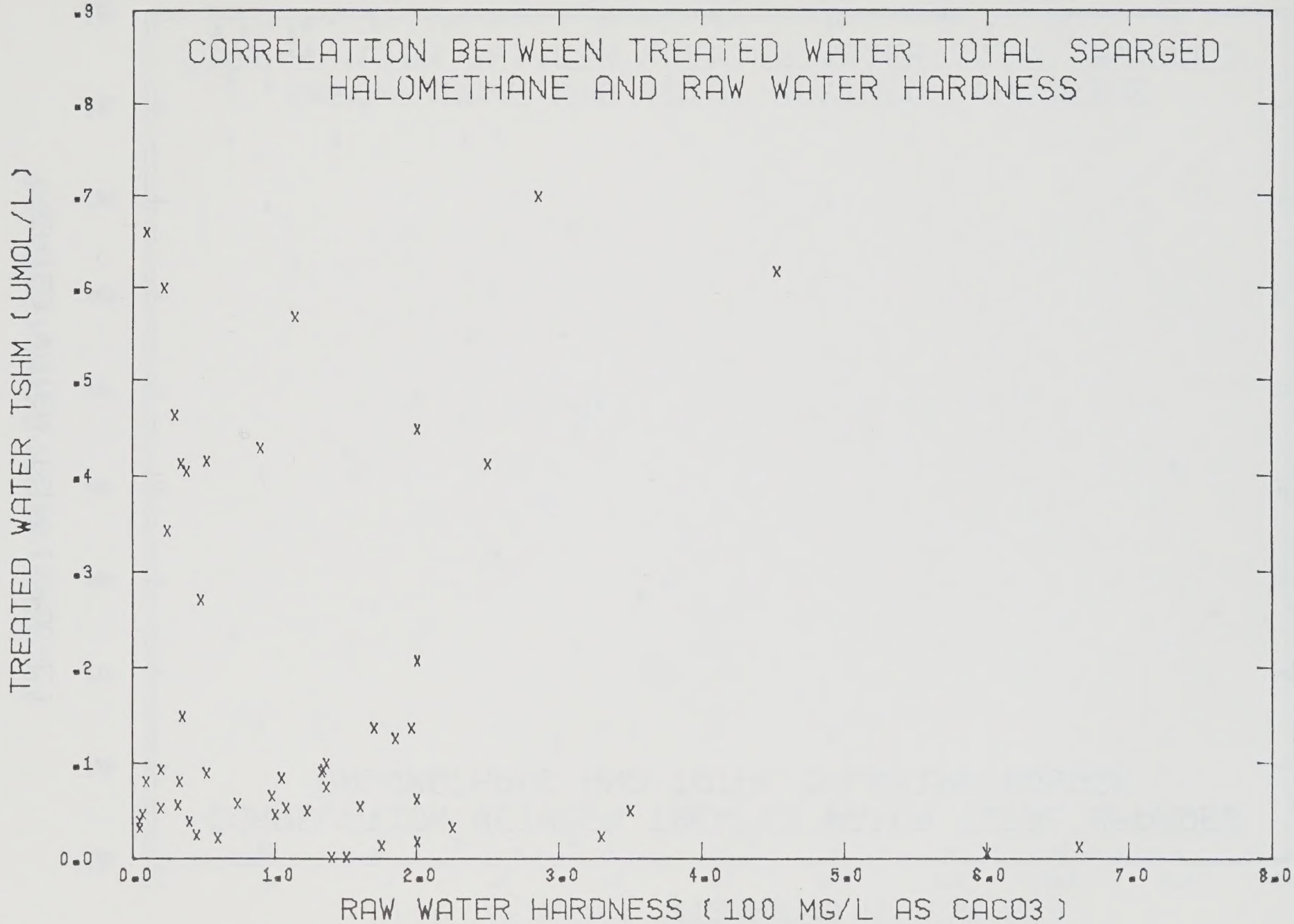

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND RAW WATER HARDNESS
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
RAW WATER HARDNESS (100 MG/L AS CACO3)

FIGURE 18

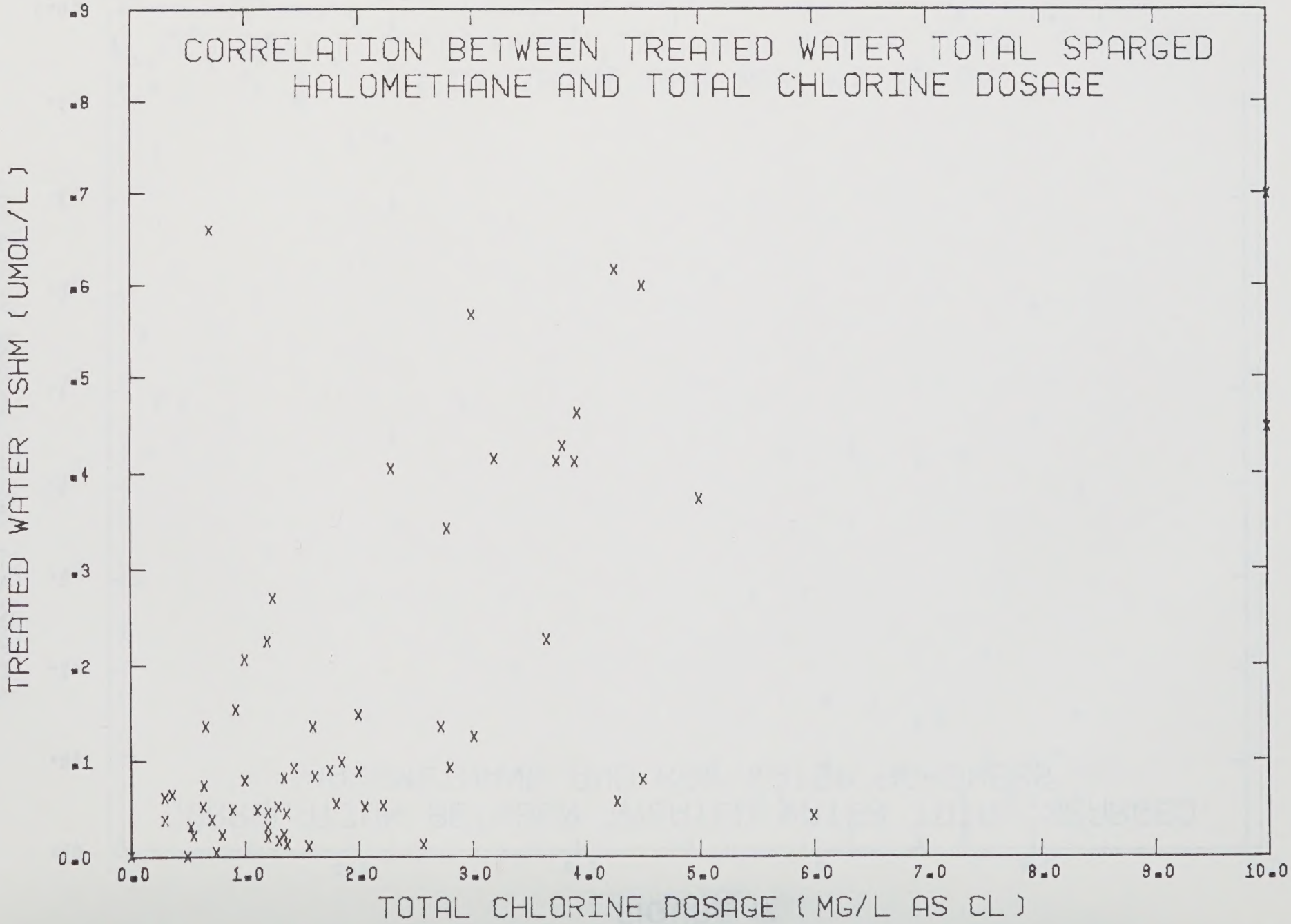

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED
HALOMETHANE AND TOTAL CHLORINE DOSAGE
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TOTAL CHLORINE DOSAGE (MG/L AS CL)

FIGURE 19

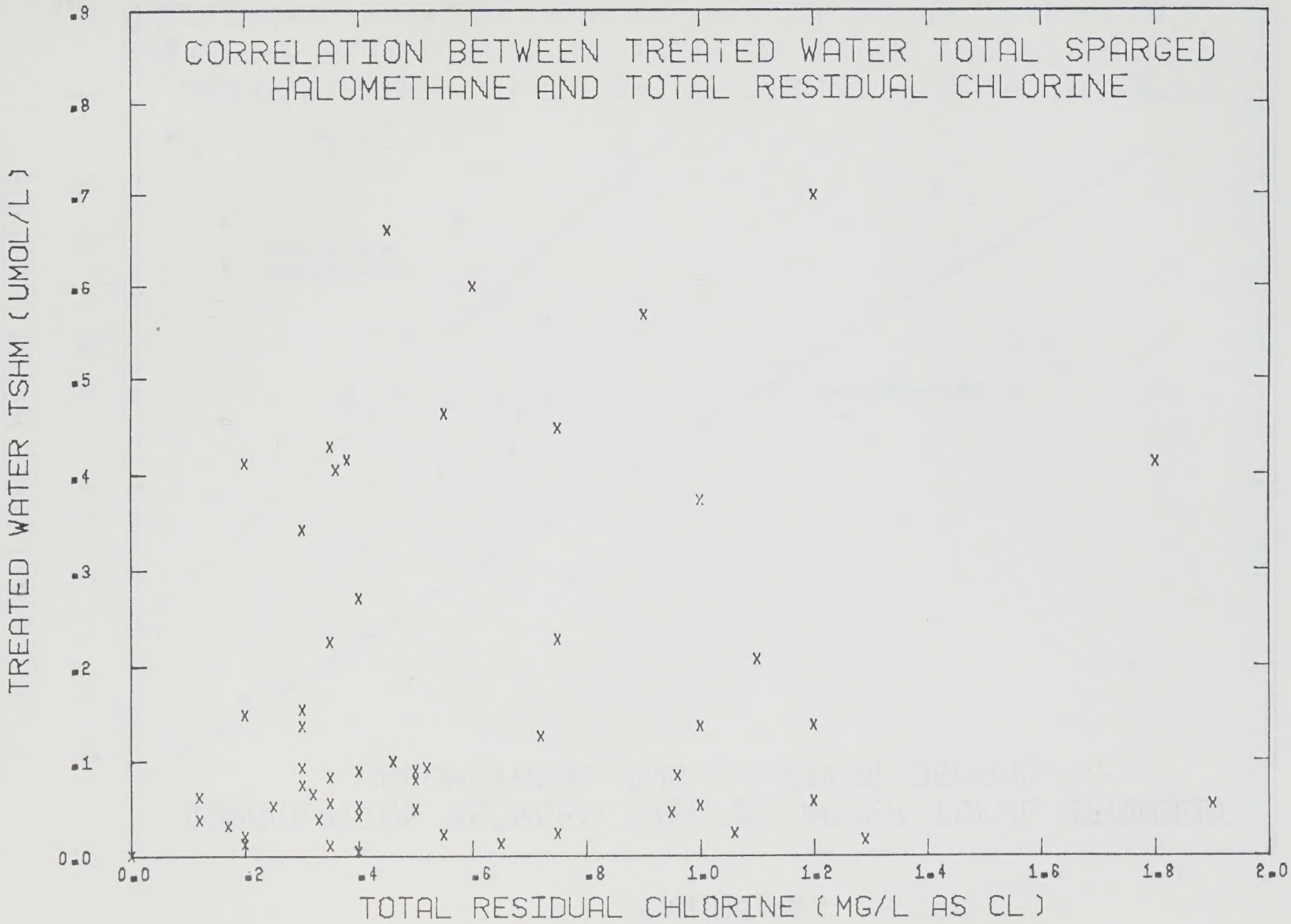

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED
HALOMETHANE AND TOTAL RESIDUAL CHLORINE
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
TOTAL RESIDUAL CHLORINE (MG/L AS CL)

FIGURE 20

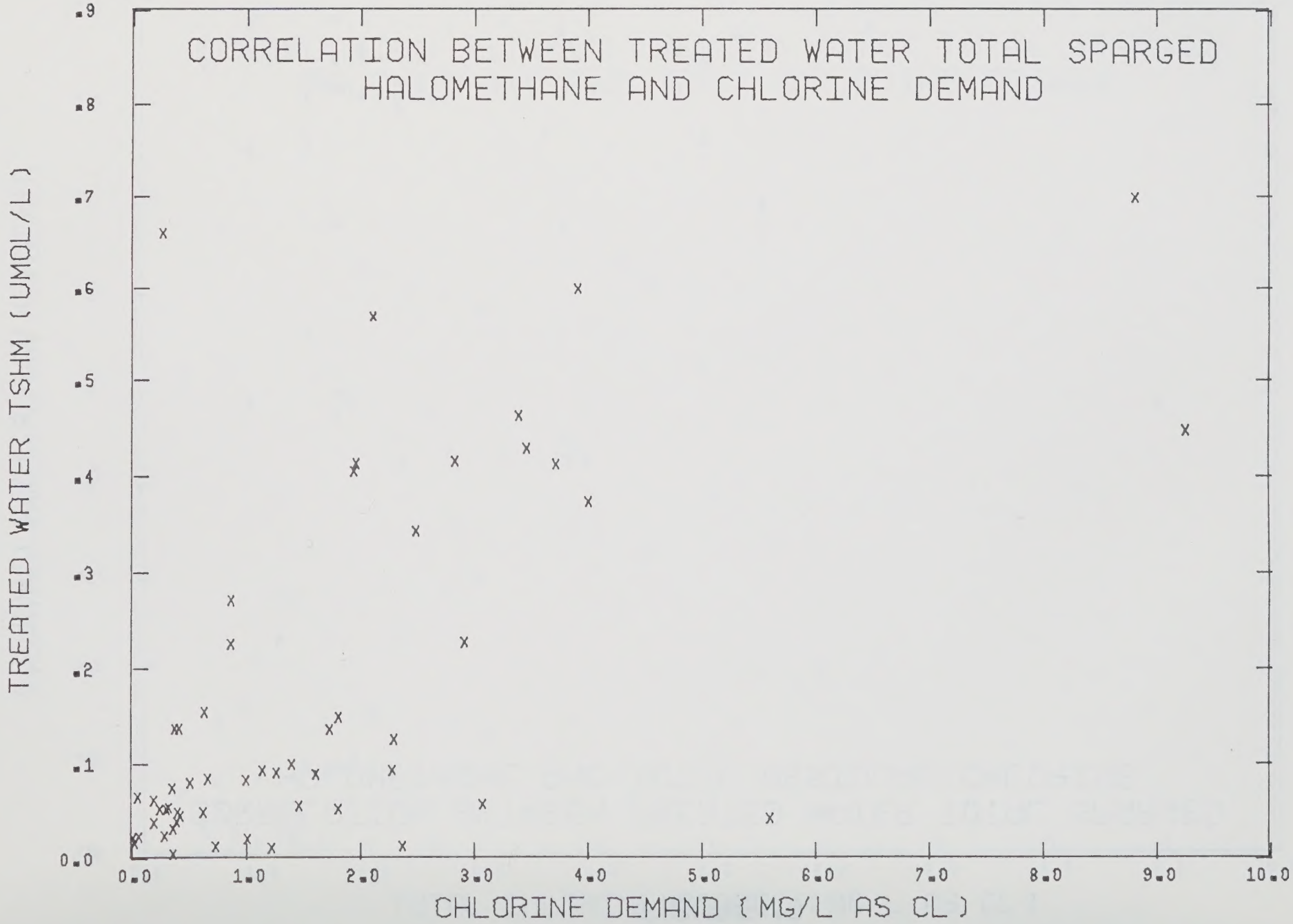

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND CHLORINE DEMAND
TREATED WATER TSHM (UMOL/L)
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
CHLORINE DEMAND (MG/L AS CL)

FIGURE 21

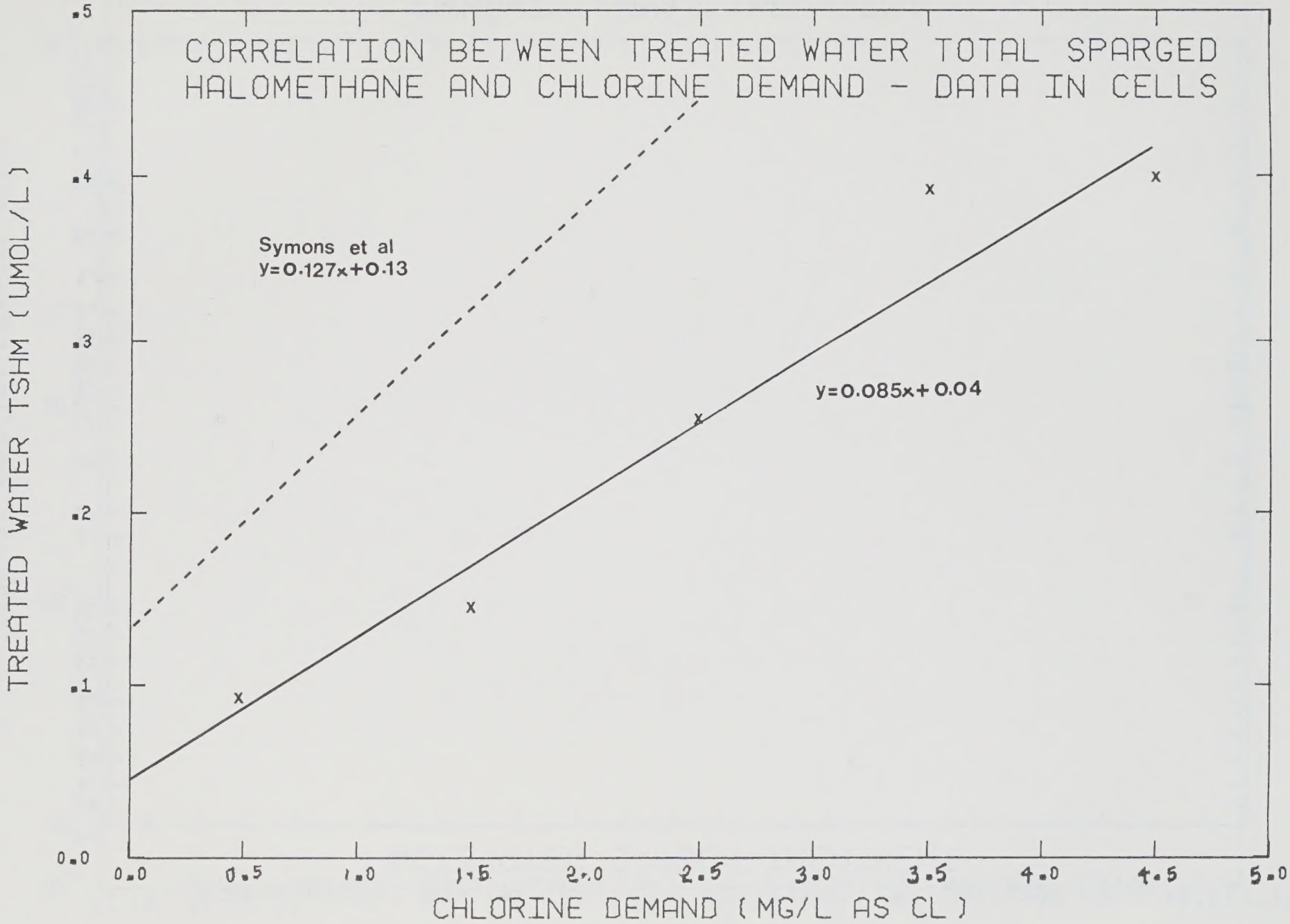

CORRELATION BETWEEN TREATED WATER TOTAL SPARGED HALOMETHANE AND CHLORINE DEMAND - DATA IN CELLS
Symons et al
y=0.127x+0.13
y=0.085x+0.04
TREATED WATER TSHM (UMOL/L)
.5
.4
.3
.2
.1
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
CHLORINE DEMAND (MG/L AS CL)

FIGURE 22

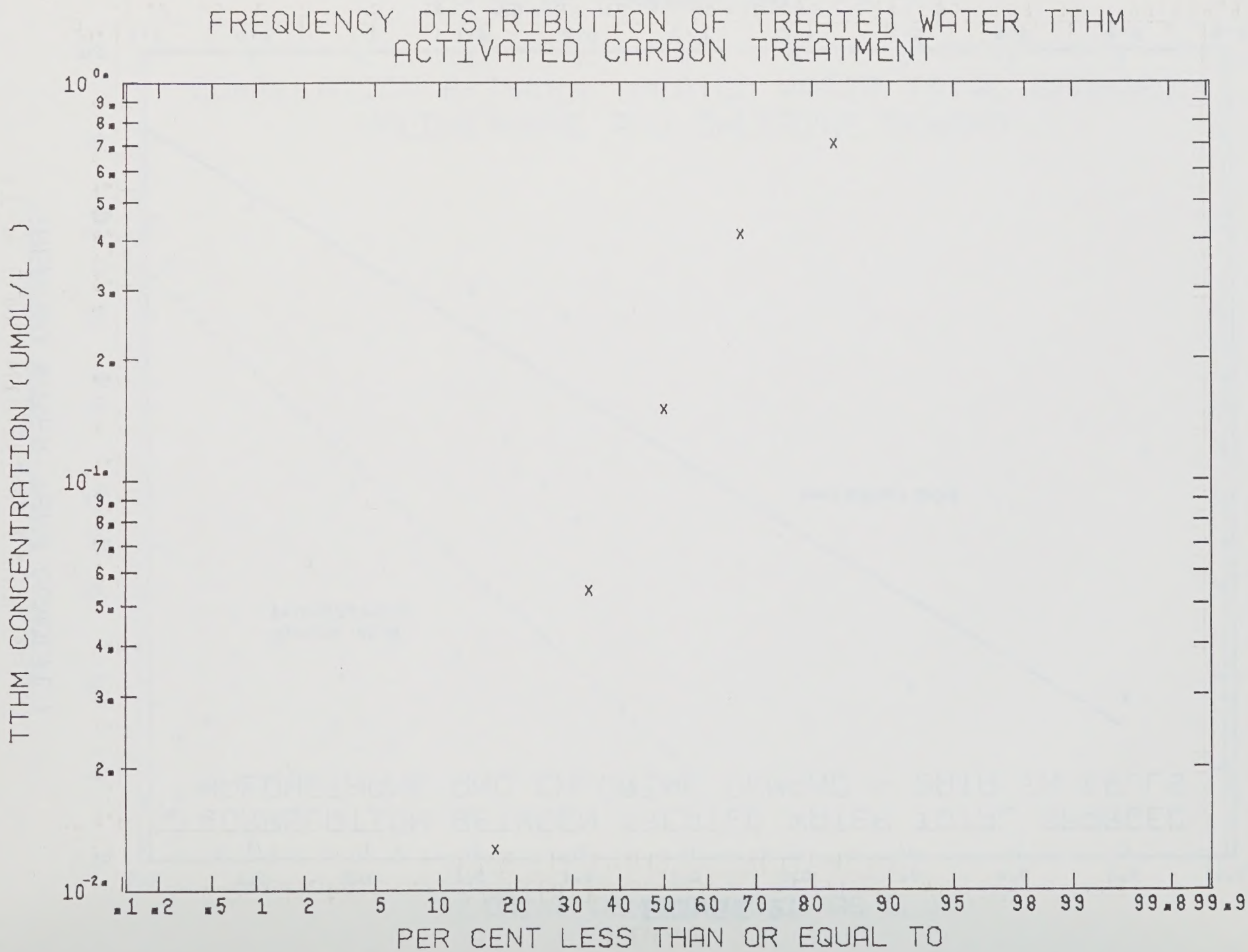

FREQUENCY DISTRIBUTION OF TREATED WATER TTHM
ACTIVATED CARBON TREATMENT
TTHM CONCENTRATION (UMOL/L)
PER CENT LESS THAN OR EQUAL TO
10^0
10^-1
10^-2
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 23

FREQUENCY DISTRIBUTION OF TREATED WATER TTHM
AMMONIA (NH3) TREATMENT

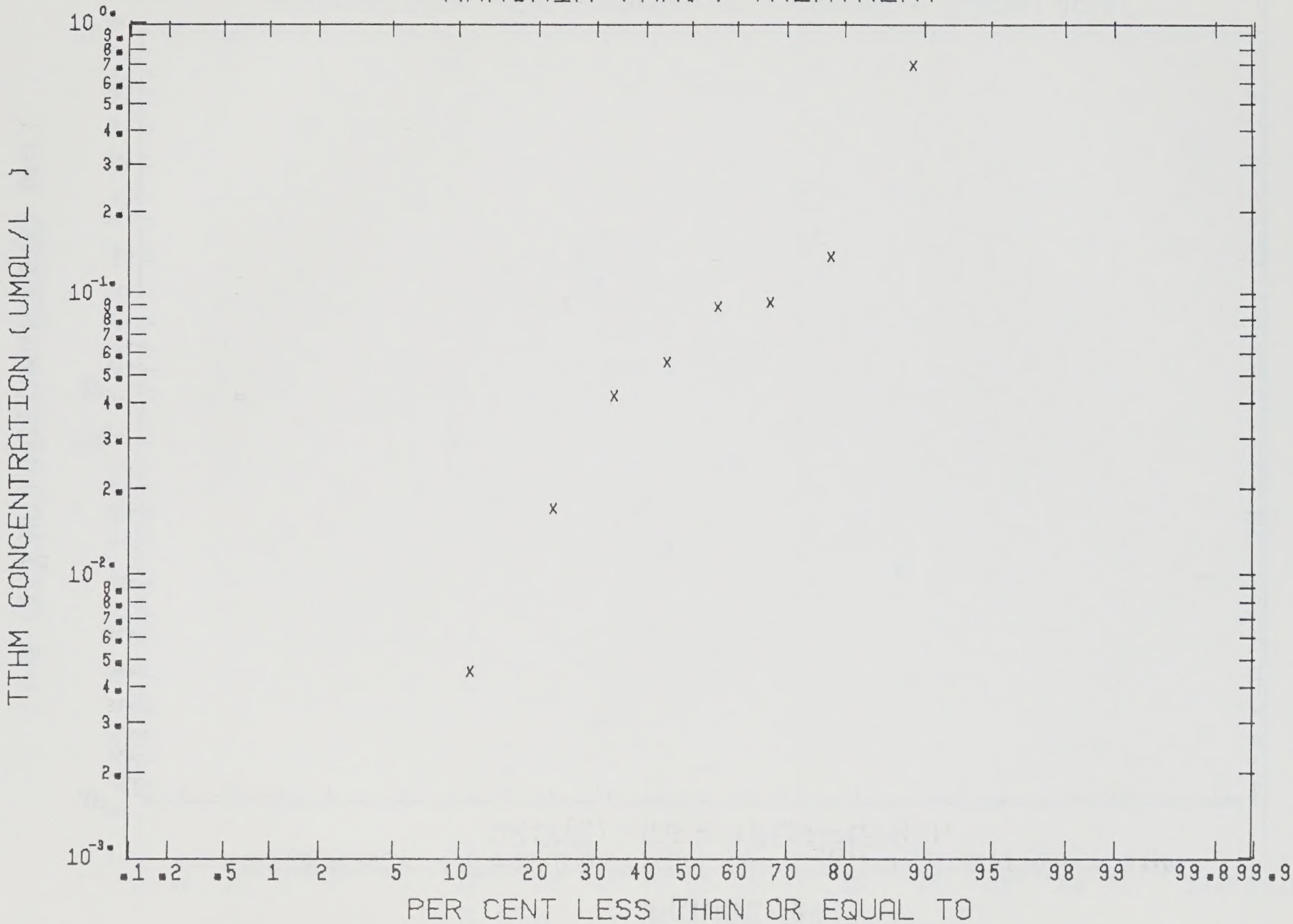


FIGURE 24

FREQUENCY DISTRIBUTION OF TREATED WATER TTHM
OZONE (O3) TREATMENT

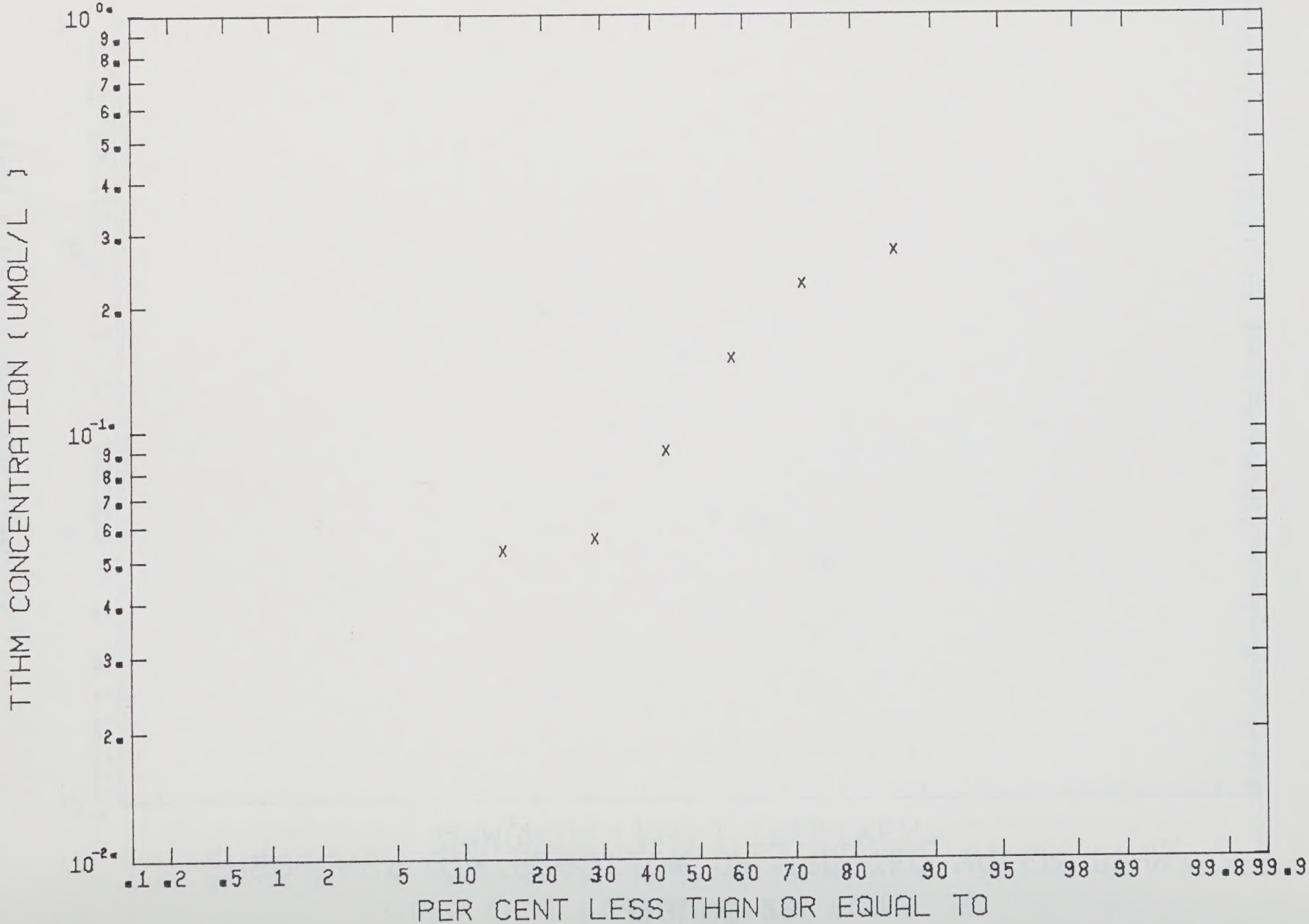
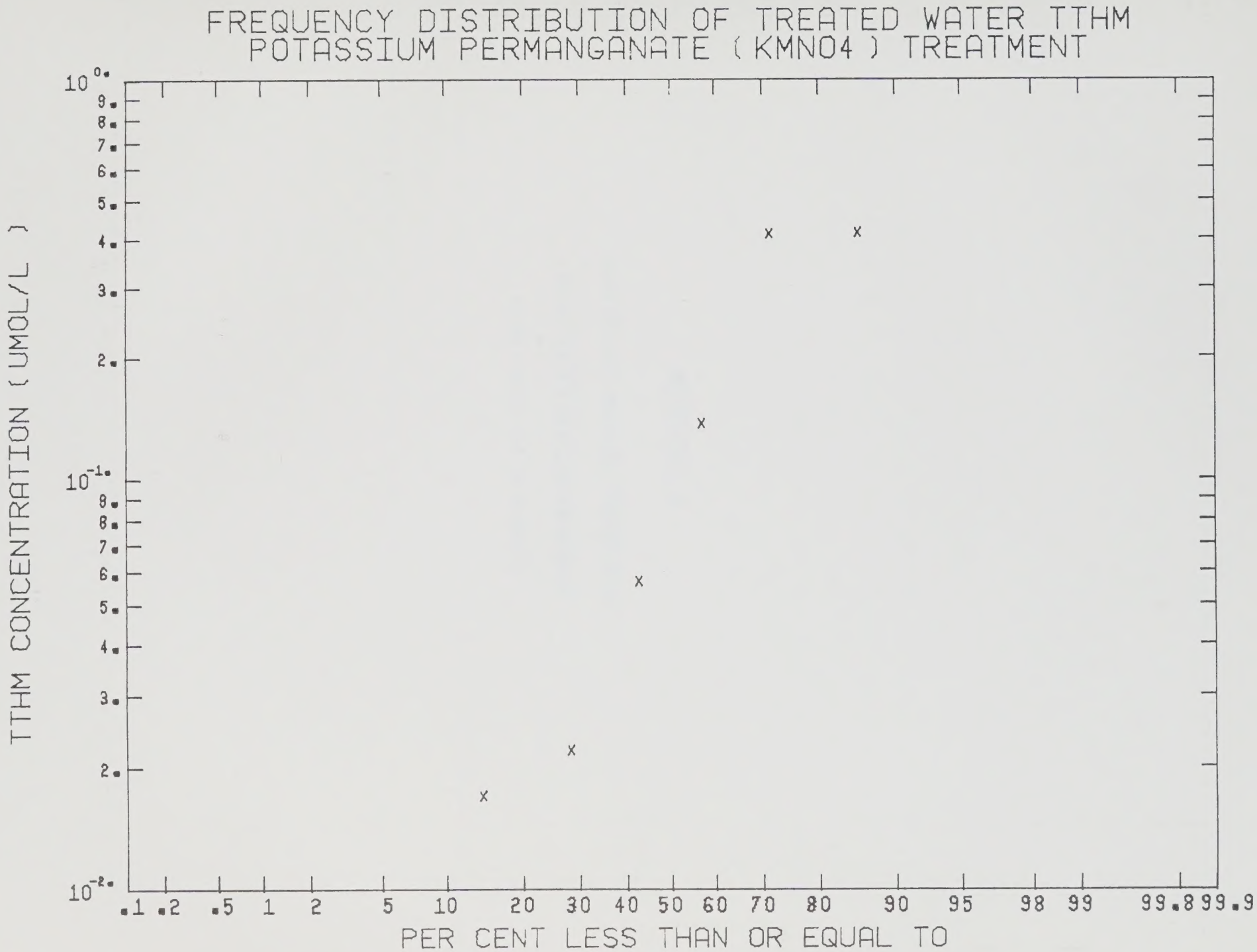


FIGURE 25


FREQUENCY DISTRIBUTION OF TREATED WATER TTHM
POTASSIUM PERMANGANATE (KMNO4) TREATMENT
TTHM CONCENTRATION (UMOL/L)
PER CENT LESS THAN OR EQUAL TO
10^0
10^-1
10^-2
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

APPENDIX 1

SURVEY OF WATER TREATMENT PRACTICES QUESTIONNAIRES AND FIELD DATA SHEETS

Reference: 2038.1 National Inventory of Halomethanes

Dear Sir:

IEC International Environmental Consultants Ltd., Toronto has been retained by Health and Welfare Canada to conduct a water sampling survey at water purification plants in seventy communities across Canada. The sampling program and subsequent sample analyses are being undertaken to determine the presence and nature of chlorinated organic materials and trace metals in raw and treated drinking water in each community. Please note that this survey in no way implies any problem or contamination of your drinking water. This is a routine survey.

The attached questionnaire is designed to summarize the basic water treatment processes and standard operating practices at each water purification plant. This information will be evaluated by Health and Welfare Canada to determine if operating and site specific factors have any significant effect on the presence or absence of chlorinated organics and trace metals in drinking water.

An IEC technician will visit your water purification plant to collect samples and pertinent operating data. Our technician plans to visit your plant on and this date will be confirmed approximately 48 hours in advance.

... 2

Page 2

On behalf of Health and Welfare Canada, I would very much appreciate your assistance and cooperation both in completing the enclosed questionnaire, and during the sampling at your water purification plant. Please hold the completed questionnaire until IEC's technician visits your plant and has an opportunity to review it with you.

I hope this does not greatly inconvenience you or any of your staff. Thank you for your cooperation.

Yours very truly

IEC INTERNATIONAL ENVIRONMENTAL CONSULTANTS LTD.

D.G. Langley, Vice President

DGL/jh
Encl.

SURVEY OF WATER TREATMENT PRACTICES
FOR HEALTH AND WELFARE CANADA

1. Treatment Plant Address: _____
_____ Plant Telephone No. _____

2. Questionnaire Completed By: _____ Title: _____

1. Water Source: Lake: _____, River: _____, Well: _____, Other: _____
Name: _____, Name: _____, No. _____,

2. Raw Water Quality: pH _____, Hardness _____ppm, Turbidity _____JTU, Colour _____ Hazen Unit
or _____Pt-Co

3. Average Daily Pumpage: _____ Imperial Gallons

TYPE OF TREATMENT	Flocculation	Sedimentation	Filtration multi Media	Filtration sand	Carbon Adsorption	Aeration	Cl_2	Ozone	Fluoride	Other
1. Order Of Treatment:	_____	_____	____	____	_____	_____	____	____	_____	____
Example: A treatment plant using prechlorination, flocculation, sedimentation, sand filtration, followed by post chlorination would be reporting as follows:	2	3	____	4	_____	____	1,5	____	____	____

2. Storage Capacity for Treated Water: _____ Imperial Gallons

Chemicals Added	Chlorine (as Cl_2)	Ozone (as O_3)	Fluorine (as F_2)	Alum (as $Al_2(SO_4)_3.14H_2O$)	Lime (as CaO)	Others ( )	
1. Average Concentration added (ppm)	_____	____	_____	_____	_____	_____	_____
2. Quantity Used Per Yr.	_____	____	_____	_____	_____	_____	_____

3. Check Appropriate Control System for Cl_2 or F_2 Addition:
1. Manual Adjust - Constant Rate _____.
2. Flow Proportional Alone _____.
3. Residual Control Alone _____.
4. Flow Proportional and Residual Control _____.

4. Is there any seasonal variation in the types or quantities of chemicals used?

Explain: _____

Questionnaire From:

IEC International Environmental Consultants Ltd.
5233 Dundas Street West
Suite 410
Islington
Ontario M9B 1A6
1-416-236-1077

FIELD DATA SHEET

IDENTIFICATION

LOCATION: _____ DATE: _____

_____

CONTACT AT PLANT: _____

_____

SAMPLE DATA

WATER SAMPLE:	RAW	TREATED	STATION 1	STATION 2
DESCRIPTION OF SAMPLE SOURCE:	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
TIME SAMPLED:	_____	_____	_____	_____
SAMPLE pH:	_____	_____	_____	_____
TEMP (°C):	_____	_____	_____	_____

PROCESS PARAMETERS

CHEMICAL:	Cl_2	OZONE	ALUM	FLUORIDE	OTHERS
DOSAGE (ppm)		_____	_____	_____	_____
Pre	_____				
Post	_____				
Residual	_____		Time last measured	_____	

TIME OF LAST BACKWASH _____

NOTES

APPENDIX 2

HALOMETHANE ANALYTICAL DATA

ANALYTICAL RESULTS FOR HALOMETHANES IN WATER

Location	Sample Numbers	Location	Sample Numbers
Toronto, Ont.	5 - 8	Prince Albert, Sask.	147 - 150
Belleville, Ont.	9 - 12	Saskatoon, Sask.	151 - 154
Smiths Falls, Ont.	13 - 16	Levis, Que.	155 - 158
Ottawa, Ont.	17 - 20	Quebec, Que.	159 - 162
Brantford, Ont.	21 - 24	Riviere-du-Loup, Que.	163 - 166
Windsor, Ont.	25 - 28	Bathurst, N.B.	167 - 170
Cayuga, Ont.	29 - 32	Fredericton, N.B.	171 - 174
Niagara, Ont.	33 - 36	Saint John, N.B.	175 - 178
Barrie, Ont.	37 - 40	Swift Current, Sask.	179 - 182
Lachine, Que.	41 - 44	Medicine Hat, Alta.	183 - 186
Longueuil, Que.	45 - 48	Lethbridge, Alta.	187 - 190
Montreal, Que.	49 - 52	Calgary, Alta.	191 - 194
Laval, Que.	53 - 56	Moncton, N.B.	195 - 198
Pierrefonds, Que.	57 - 60	Charlottetown, P.E.I.	199 - 202
Hudson, Que.	61 - 64	Port Hawkesbury, N.S.	203 - 206
Hull, Que.	65 - 68	Truro, N.S.	207 - 210
Thetford, Que.	69 - 72	Dartmouth, N.S.	211 - 214
Trois Rivieres, Que.	73 - 76	Edmonton, Alta.	215 - 218
Cap-de-la-Madeleine, Que.	77 - 80	Vermillion, Alta.	219 - 222
Shawinigan, Que.	81 - 84	Halifax, N.S.	223 - 226
Sudbury, Ont.	85 - 88	High Prairie, Alta.	227 - 230
Thunder Bay, Ont.	89 - 92	Grand Prairie, Alta.	231 - 234
Winnipeg, Man.	93 - 96	Dawson Creek, B.C.	235 - 238
Selkirk, Man.	97 - 100	Rimouski, Que.	239 - 242
Granby, Que.	101 - 104	Prince George, B.C.	243 - 246
Magog, Que.	105 - 108	Kamloops, B.C.	247 - 250
Sherbrooke, Que.	109 - 112	Kelowna, B.C.	251 - 254
Windsor, Que.	113 - 116	Penticton, B.C.	255 - 258
Drummondville, Que.	117 - 120	Vancouver, B.C. no. 1	259 - 262
St. Eustache, Que.	123 - 126	Vancouver, B.C. no. 2	263 - 266
Portage-La-Prairie, Man.	127 - 130	Victoria, B.C.	267 - 270
Brandon, Man.	131 - 134	Nanaimo, B.C.	271 - 274
Swan River, Man.	135 - 138	Clarenville, Nfld.	275 - 278
Regina, Sask.	139 - 142	Grand Falls, Nfld.	279 - 282
Yorkton, Sask.	143 - 146	St. John's, Nfld.	283 - 286

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
BRITISH COLUMBIA												
Dawson Creek												
	Raw	Jan. 17, 1977	235	3.9*	0.50*	0.09*	0.05*	1.6	<0.1	<0.1	<1	5.5
	Treated		236	16	0.42	0.09	0.03	16	0.3	<0.1	<1	7.0
	Station 1		237	18*	1.0*	0.58*	1.3*	19	0.2	<0.1	<1	5.0
	Station 2		238	17	0.60	0.10	0.10	19	0.2	<0.1	<1	6.0
Kamloops												
	Raw	Jan. 20, 1977	247	0.7	0.05	0.05	0.04	<0.5	<0.1	<0.1	<1	1.5
	Treated		248	18	0.60	0.03	0.03	23	0.3	<0.1	<1	1.5
	Station 1		249	25	0.96	0.03	0.03	36	0.5	<0.1	<1	0.5
	Station 2		250	28	1.2	0.04	0.04	36	1.0	<0.1	<1	1.5
Kelowna												
	Raw	Jan. 20, 1977	251	0.9*	0.37*	0.55*	1.0*	0.8	<0.1	<0.1	<1	0
	Treated		252	5.0	0.42	0.12	0.08	5.2	<0.1	<0.1	<1	2.0
	Station 1		253	25	3.2	0.23	0.04	31	3.3	<0.1	<1	1.5
	Station 2		254	20	2.6	0.39	0.03	24	2.0	<0.1	<1	1.0
Nanaimo												
	Raw	Jan. 26, 1977	271	0.51	0.05	0.03	0.02	0.8	<0.1	<0.1	<1	3.0
	Treated		272	6.7*	0.65*	0.51*	1.2*	8.4	<0.1	<0.1	<1	3.0
	Station 1		273	6.0	0.46	0.07	0.10	7.5	<0.1	<0.1	<1	3.5
	Station 2		274	15	0.90	0.05	0.05	20	0.6	<0.1	<1	3.0
Penticton												
	Raw	Jan. 21, 1977	255	0.6	0.06	0.05	0.03	1.1	<0.1	<0.1	<1	7.0
	Treated		256	11	0.14	0.05	0.02	16	<0.1	<0.1	<1	6.5
	Station 1		257	66*	1.5*	0.34*	0.75*	68	1.0	<0.1	<1	6.5
	Station 2		258	39	0.86	0.06	0.10	51	0.7	<0.1	<1	6.0
Prince George												
	Raw - No Sample	Jan. 18, 1977	243	-	-	-	-	-	-	-	-	-
	Treated		244	3.8*	0.55*	0.53*	1.4*	2.5	<0.1	<0.1	<1	1.5
	Station 1		245	4.5	0.33	0.07	0.12	3.6	<0.1	<0.1	<1	1.0
	Station 2		246	4.8	1.5	1.5	0.04	3.6	<0.1	<0.1	<1	0

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
BRITISH COLUMBIA (Cont'd)												
Vancouver No. 1												
	Raw	Jan. 24, 1977	259	1.6	0.10	0.08	0.04	1.3	<0.1	<0.1	<1	3.0
	Treated		260	4.5	0.11	0.06	0.03	6.4	<0.1	<0.1	<1	3.0
	Station 1		261	8.9	0.24	0.06	0.02	14	<0.1	<0.1	<1	3.0
	Station 2		262	11	0.25	0.05	0.02	17	<0.1	<0.1	<1	5.0
Vancouver No. 2												
	Raw	Jan. 24, 1977	263	1.3*	0.44*	0.56*	1.2*	1.9	<0.1	<0.1	<1	3.0
	Treated		264	3.7	0.11	0.07	0.05	6.3	<0.1	<0.1	<1	3.0
	Station 1		265	11	0.26	0.12	0.03	17	<0.1	<0.1	<1	3.0
	Station 2		266	13	0.24	0.02	0.03	18	<0.1	<0.1	<1	3.0
Victoria												
	Raw	Jan. 25, 1977	267	1.1*	0.46*	0.65*	1.4*	0.8	<0.1	<0.1	<1	3.5
	Treated		268	4.6	0.51	0.09	0.11	7.4	0.4	<0.1	<1	4.0
	Station 1		269	5.1	0.73	0.07	0.05	7.2	0.5	<0.1	<1	4.0
	Station 2		270	4.1	0.64	0.08	0.03	5.2	0.4	<0.1	<1	2.0
ALBERTA												
Calgary												
	Raw	Jan. 12, 1977	191	1.4*	0.34*	0.53*	1.4*	0.9	<0.1	<0.1	<1	1.5
	Treated		192	6.5	1.05	0.15	0.07	3.6	0.6	0.2	<1	1.5
	Station 1		193	7.0	0.93	0.08	0.04	6.4	0.6	<0.1	<1	0.5
	Station 2		194	6.2	0.78	0.10	0.04	5.3	0.6	<0.1	<1	3.0
Edmonton												
	Raw	Jan. 13, 1977	215	0.9	0.34	0.09	0.21	2.4	<0.1	<0.1	<1	1.0
	Treated		216	6.0	0.51	0.09	0.04	6.2	<0.1	<0.1	<1	2.0
	Station 1		217	8.0	0.31	0.05	0.03	6.5	<0.1	<0.1	<1	1.0
	Station 2		218	10.2	0.64	0.09	<0.01	6.8	<0.1	<0.1	<1	1.0
	Repeat		218	9.8	0.57	0.37	0.02					

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
ALBERTA (Cont'd)												
Grand Prairie												
	Raw	Jan. 16, 1977	231	1.3*	0.44*	0.60*	1.4*	2.0	<0.1	<0.1	<1	1.5
	Treated		232	24	0.63	0.10	0.14	25	0.5	<0.1	<1	3.5
	Station 1		233	49	1.4	0.05	0.07	52	1.8	<0.1	<1	4.0
	Station 2		234	50	1.5	0.05	0.06	54	1.6	<0.1	<1	6.0
	Treated Repeat		232	24	0.67	0.18	0.04					
High Prairie												
	Raw	Jan. 15, 1977	227	1.6*	0.40*	0.39*	0.74*	8.0	0.1	<0.1	<1	48.0
	Treated		228	4.8	1.6	0.41	0.18	6.2	1.6	<0.1	<1	27.0
	Station 1		229	5.1	1.8	0.42	0.13	5.4	1.7	<0.1	<1	26.0
	Station 2		230	5.0	1.8	0.42	0.10	5.4	1.6	<0.1	<1	27.0
	Repeat		230					5.5	1.4	<0.1	<1	
Lethbridge												
	Raw	Jan. 11, 1977	187	1.5*	0.47*	0.64*	1.4*	1.0	0.3	<0.1	<1	2.0
	Treated		188	1.7	0.29	0.08	0.16	1.4	<0.1	<0.1	<1	0.5
	Station 1		189	1.6	0.26	0.04	0.05	1.6	<0.1	<0.1	<1	2.0
	Station 2		190	1.5	0.24	0.03	0.04	1.2	0.2	<0.1	<1	3.0
Medicine Hat												
	Raw	Jan. 11, 1977	183	1.3	0.41	0.06	0.04	2.6	<0.1	<0.1	<1	1.0
	Treated		184	13	2.6	0.24	0.05	16	2.3	<0.1	<1	3.0
	Station 1		185	13	2.9	0.30	0.06	16	2.8	0.3	<1	3.0
	Station 2		186	15	3.3	0.32	0.05	19	3.2	0.3	<1	3.0
Vermillion												
	Raw	Jan. 14, 1977	219	3.4*	0.38*	0.09*	0.07*	0.7	<0.1	<0.1	<1	6.0
	Treated		220	1.4	0.12	0.07	0.04	1.0	<0.1	<0.1	<1	9.0
	Station 1		221	4.1	0.89	0.15	0.03	3.6	0.8	<0.1	<1	11.0
	Station 2		222	4.1	0.93	0.14	0.03	4.8	0.8	<0.1	<1	16.0
	Raw Repeat		219					0.7	<0.1	<0.1	<1	

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis				Direct Injection				T.O.C. mg/l
				$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	
SASKATCHEWAN												
Prince Albert												
	Raw	Jan. 7, 1977	147	0.6	0.02	0.05	<0.01	0.8	0.3	<0.1	<1	1.5
	Treated		148	1.4	0.10	0.02	0.03	3.2	0.1	<0.1	<1	2.0
	Station 1		149	1.9	0.15	0.02	0.02	1.8	<0.1	<0.1	<1	1.0
	Station 2		150	1.8	0.16	0.03	0.02	1.8	<0.1	<0.1	<1	1.5
Regina												
	Raw	Dec. 17, 1976	139	<0.1*	0.60*	0.30*	0.5*	1.4	0.4	<0.1	<1	9.0
	Treated		140	34	23	4.6	0.1	60	29	5.8	<1	8.0
	Station 1		141	36	33	6.2	0.1	82	44	7.0	<1	8.5
	Station 2		142	29	27	4.9	0.1	51	22	4.5	<5	8.0
Saskatoon												
	Raw	Jan. 7, 1977	151	1.8	0.37	0.36	0.09	0.7	0.2	<0.1	<1	2.5
	Treated		152	15	1.6	0.22	0.16	17.5	1.5	<0.1	<1	2.0
	Station 1		153	17*	2.4*	1.1*	2.2*	17.5	1.7	<0.1	<1	1.5
	Station 2		154	16.5	1.7	0.31	0.21	18.0	1.6	<0.1	<1	1.5
Swift Current												
	Raw	Jan. 10, 1977	179	2.6	0.26	0.10	0.17	3.2	<0.1	<0.1	<1	2.5
	Treated		180	42	9.0	1.00	0.13	54	11	0.8	<1	5.0
	Station 1		181	43	9.5	1.03	0.11	57	11.5	0.8	<1	1.5
	Station 2		182	42	10.9	1.20	0.11	59	14.0	0.9	<1	1.5
Yorkton												
	Raw	Jan. 6, 1977	143	1.3	0.13	0.11	0.09	1.8	1.0	1.2	<1	2.5
	Treated		144	1.2	0.14	0.05	0.06	1.4	1.5	1.6	<1	2.5
	Station 1		145	2.5	1.3	0.60	0.12	2.1	1.8	0.9	<1	3.0
	Station 2		146	2.0	0.24	0.11	0.17	1.2	<0.1	<0.1	<1	3.5
	Raw Repeat		143					<0.5	0.5	<0.1	<1	

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
MANITOBA												
Brandon												
	Raw	Dec. 15, 1976	131	1.3	<0.01	<0.01	<0.1	1.2	0.4	<0.1	<1	11.0
	Treated		132	4.8	1.4	0.15	<0.1	6.6	1.2	<0.1	<1	5.5
	Station 1		133	14	4.6	0.55	<0.1	19	3.9	0.5	<1	9.5
	Station 2		134	14	5.0	0.63	<0.1	19	3.8	0.6	<1	9.0
	Station 1 Repeat		133	15	5.1	0.8	<0.1					
Portage La Prairie												
	Raw	Dec. 14, 1976	127	1.8	0.9	0.8	0.1	2.4	1.3	0.4	<1	9.0
	Treated		128	2.6	0.05	0.01	<0.1	2.0	<0.1	<0.1	<1	6.5
	Station 1		129	2.8	0.35	0.01	<0.1	2.8	0.5	<0.1	<1	5.5
	Station 2		130	2.9	0.20	0.01	<0.1	1.8	0.2	<0.1	<1	4.5
	Treated Repeat		128	2.0	0.56	0.30	<0.1					
Selkirk												
	Raw	Dec. 14, 1976	97	<0.1*	0.39*	0.38*	0.6*	2.5	<0.1	<0.1	<1	0
	Treated		98	0.5	0.02	0.01	<0.1	1.5	<0.1	<0.1	<1	2.0
	Station 1		99	<0.1	0.22	0.15	0.2	2.1	<0.1	<0.1	<1	0.5
	Station 2		100	<0.1	0.12	0.17	<0.1	1.3	<0.1	<0.1	<1	2.5
Swan River												
	Raw	Dec. 15, 1976	135	0.8	0.32	0.22	0.01	1.0	<0.1	<0.1	<1	6.5
	Treated		136	6.2	0.86	0.05	<0.1	7.5	1.0	<0.1	<1	5.0
	Station 1		137	4.7	0.70	0.01	<0.1	8.5	0.8	<0.1	<1	5.0
	Station 2		138	7.1	0.75	0.01	<0.1	8.8	0.7	<0.1	<1	6.0
	Treated Repeat		136	6.2	0.68	0.01	<0.1	8.5	0.8	<0.1	<1	
	Station 1 Repeat		137	6.9	0.35	<0.01	<0.1					
	Station 2 Repeat		138	5.9	0.40	<0.01	<0.1					

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
MANITOBA (Cont'd)												
Winnipeg												
	Raw	Dec. 13, 1976	93	<0.1	0.04	<0.01	<0.1	0.7	<0.1	<0.1	<1	9.5
	Treated		94	68	7.5	0.18	<0.1	73	4.6	<0.1	<1	10.5
	Station 1		95	73	5.4	0.20	<0.1	84	6.3	<0.1	<1	9.0
	Station 2		96	72	5.5	0.20	<0.1	87	6.5	<0.1	<1	9.0
ONTARIO												
Barrie												
	Raw	Nov. 24, 1976	37	<0.1	0.16	0.05	<0.1	1.3	<0.1	<0.1	<1	2.0
	Treated		38	3.6	0.06	0.04	0.3	2.9**	<0.1**	<0.1**	<1**	12.0**
	Station 1		39	1.8	0.40	0.03	0.1	2.6	0.2	<0.1	<1	3.5
	Station 2		40	1.3	0.25	0.02	<0.1	10*	0.8*	<0.1*	<1*	3.5
	Repeat		40					2.9	<0.1	<0.1	<1	
Belleville												
	Raw	Nov. 18, 1976	9	1.3	0.21	0.08	<0.1	2.2	<0.1	<0.1	<1	10.5
	Treated		10	64	5.1	0.01	<0.1	62	6.3	<0.1	<1	7.0
	Station 1		11	58	5.5	0.02	<0.1	69	7.4	<0.1	<1	6.5
	Station 2		12	56	5.5	0.02	<0.1	68	7.8	<0.1	<1	7.0
	Treated Repeat		10	57	7.0	2.6	0.08					
Brantford												
	Raw	Nov. 22, 1976	21	8.3	0.01	0.06	0.04	8.6	<0.1	<0.1	1	7.0
	Treated		22	74	12.6	0.27	0.2	114	20.7	1.0	<1	4.5
	Station 1		23	75	13.0	0.27	<0.1	105	16.6	1.0	<1	4.0
	Station 2		24	73	11.7	0.25	0.3	102	14.5	1.1	<1	6.0
Cayuga												
	Raw	Nov. 23, 1976	29	<0.1	0.12	0.10	0.1	1.6	<0.1	<0.1	<1	5.5
	Treated		30	38	8.3	0.70	0.1	61	10.8	0.9	<1	4.5
	Station 1		31	62	18.5	1.3	<0.1	103	20.5	1.7	<1	4.0
	Station 2		32	56	17.5	1.2	<0.1	86	16.3	1.4	<1	3.0

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
ONTARIO (Cont'd)												
Niagara												
	Raw	Nov. 23, 1976	33	<0.1	0.50	0.47	0.7	3.9*	<0.1*	<0.1*	<1*	2.0
	Treated		34	7.6	4.7	1.4	0.2	15	5.2	<0.1	<1	2.0
	Station 1		35	8.0	5.2	1.4	0.2	11	4.7	1.7	<1	0
	Station 2		36	6.4	5.2	1.5	0.1	10	4.9	1.6	<1	1.5
	Raw Repeat		33					1.0	<0.1	<0.1	<1	
Ottawa												
	Raw	Feb. 11, 1977	17	3.5	0.09	0.10	0.02	3.1	<0.1	<0.1	<1	9.5
	Treated		18	9.4	0.29	0.03	0.01	9.9	0.2	<0.1	<1	4.0
	Station 1		19	10.1	0.32	0.05	0.01	9.5	0.1	<0.1	<1	3.0
	Station 2		20	10.7	0.34	0.02	0.01	10.7	0.2	<0.1	<1	3.5
Smiths Falls												
	Raw	Feb. 10, 1977	13	0.9	0.07	0.12	0.03	1.6	<0.1	<0.1	<1	4.5
	Treated		14	6.0	0.34	0.04	0.03	6.8	0.3	<0.1	<1	5.0
	Station 1		15	6.0	0.41	0.16	0.03	7.0	0.2	<0.1	<1	5.0
	Station 2		16	6.8	0.44	0.04	0.02	7.3	0.4	<0.1	<1	4.5
Sudbury												
	Raw	Dec. 8, 1976	85	<0.1*	0.35*	0.40*	0.7*	<0.5**	<0.5**	<0.1**	<5**	7.0**
	Treated		86	47	1.8	<0.01	<0.1	52	1.6	<0.1	<1	3.5
	Station 1		87	48	2.0	<0.01	<0.1	50	1.3	<0.1	<1	2.5
	Station 2		88	48	1.9	<0.01	<0.1	58	1.6	<0.1	<1	2.5
Thunder Bay												
	Raw	Dec. 10, 1976	89	<0.1	<0.01	<0.01	<0.1	1.6	<0.1	<0.1	<1	2.0
	Treated		90	2.2	0.45	0.22	0.4	3.1	<0.1	<0.1	<1	2.0
	Station 1		91	6.0	1.4	0.10	<0.1	7.0	0.9	<0.1	<1	1.0
	Station 2		92	7.4	1.1	0.19	<0.1	9.7	1.1	<0.1	<1	1.5
Toronto												
	Raw	Nov. 17, 1976	5	<0.1	<0.01	<0.01	<0.1	1.2	<0.1	<0.1	<1	4.5
	Treated		6	5.5	4.9	2.9	<0.1	8.8	5.5	2.3	<1	4.5
	Station 1		7	4.6	4.7	2.3	<0.1	8.2	3.7	2.0	<1	4.5
	Station 2		8	5.9	4.0	1.4	<0.1	7.3	3.5	1.7	<1	3.0
	Treated Repeat		6	5.6	5.4	3.3	<0.1					

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
ONTARIO (Cont'd)												
Windsor												
	Raw	Nov. 22, 1976	25	1.9	0.18	0.01	<0.1	1.9	0.3	<0.1	<1	3.5
	Treated		26	6.4	1.4	0.81	0.3	6.4	2.6	1.4	<1	13.5
	Station 1		27	8.1	5.7	2.9	1.0	10.4	5.7	2.3	<1	2.5
	Station 2		28	6.0	4.7	1.7	<0.1	8.6	5.0	2.5	<1	1.5
	Treated Repeat		26	7.2	4.5	2.8	0.19	7.0	1.4	1.3	1	
QUEBEC												
Cap-de-la-Madeleine												
	Raw - No Sample	Dec. 9, 1976	77	-	-	-	-	-	-	-	-	-
	Treated		78	<0.1	<0.01	<0.01	<0.1	5.1*	<0.1*	<0.1*	<1*	0.5
	Station 1		79	<0.1	<0.01	<0.01	<0.1	1.6	<0.1	<0.1	<1	1.0
	Station 2		80	<0.1	<0.01	<0.01	<0.1	1.3	<0.1	<0.1	<1	0.5
	Treated Repeat		78					<0.5	<0.1	<0.1	<1	
Drummondville												
	Raw	Dec. 8, 1976	117	<0.1	0.01	<0.01	<0.1	5.4**	<0.5**	<0.1**	<5**	8.0**
	Treated		118	10.3	0.5	<0.01	<0.1	13	0.7	<0.1	<1	4.0
	Station 1		119	10.0	0.6	0.01	<0.1	12	0.8	<0.1	<1	5.0
	Station 2		120	9.0	0.3	<0.01	<0.1	11	0.6	<0.1	<1	4.5
Granby												
	Raw	Dec. 6, 1976	101	<0.1*	0.35*	1.3*	2.6*	<0.5**	<0.5**	<0.1**	<5**	8.5**
	Treated		102	46	4.5	0.22	0.3	69	5.9	<0.1	<1	2.0
	Station 1		103	<0.1	0.14	<0.01	<0.1	2.5	<0.1	<0.1	<1	0.5
	Station 2		104	52	5.2	0.67	0.8	74	4.9	<0.1	<1	2.5
	Station 1 Repeat		103	<0.1	<0.01	<0.01	<0.1					
	Station 1 Repeat		103	<0.1	0.13	<0.01	0.1					
	Station 2 Repeat		104	61	5.2	0.44	0.4					

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
QUEBEC (Cont'd)												
Hudson												
	Raw - No Sample	Dec. 2, 1976	61	-	-	-	-	-	-	-	-	-
	Treated		62	<0.1	<0.01	<0.01	<0.1	2.6	<0.1	<0.1	<1	1.5
	Station 1		63	<0.1	<0.01	<0.01	<0.1	1.2	<0.1	<0.1	<1	2.5
	Station 2		64	<0.1*	0.40*	0.10*	0.3*	1.2	<0.1	<0.1	<1	2.5
Hull												
	Raw	Dec. 3, 1976	65	<0.1	<0.01	<0.01	<0.1	1.2	<0.1	<0.1	<1	8.5
	Treated		66	50	1.6	<0.01	<0.1	68	2.5	0.8	<1	6.0
	Station 1		67	50	1.6	<0.01	<0.1	64	2.6	<0.1	<1	7.0
	Station 2		68	50	1.5	<0.01	<0.1	76	2.7	<0.1	<1	6.0
Lachine												
	Raw	Nov. 30, 1976	41	<0.1	<0.01	<0.01	<0.1	5.1	<0.1	<0.1	<1	8.5
	Treated		42	2.0	0.55	<0.01	<0.1	7.8	0.7	<0.1	<1	3.5
	Station 1		43	3.4	0.60	0.03	<0.1	6.8	0.9	<0.1	<1	4.5
	Station 2		44	3.1	0.70	<0.01	<0.1	7.7	0.6	<0.1	<1	4.0
Laval												
	Raw	Dec. 1, 1976	53	<0.1	<0.01	<0.01	<0.1	1.4	<0.1	<0.1	<1	8.5
	Treated		54	17.0	1.0	<0.01	<0.1	18	0.5	<0.1	<1	4.0
	Station 1		55	13.3	1.1	<0.01	<0.1	7.2**	<0.5**	0.4**	<5**	19.0**
	Station 2		56	11.8	0.80	<0.01	<0.1	21.9**	<0.5**	1.4**	<5**	24.5**
Levis												
	Raw	Jan. 5, 1976	155	1.7*	0.24*	0.22*	0.63*	<0.5	<0.1	<0.1	<1	5.5
	Sample Missing		156	-	-	-	-	-	-	-	-	-
	Station 1		157	4.2	1.2	0.51	0.19	6.5	0.8	<0.1	<1	4.0
	Station 2		158	4.2	1.0	0.20	0.20	6.3	1.2	<0.1	<1	4.5
Longueuil												
	Raw	Nov. 30, 1976	45	<0.1	<0.01	<0.01	<0.1	1.2	<0.1	<0.1	<1	6.0
	Treated		46	7.4	3.8	1.2	<0.1	10	2.4	1.3	<1	4.5
	Station 1		47	7.5	5.5	1.0	<0.1	13	5.9	1.7	<1	6.5
	Station 2		48	7.2	4.1	1.6	<0.1	12	5.8	1.7	<1	5.0

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
QUEBEC (Cont'd)												
Magog												
	Raw	Dec. 6, 1976	105	<0.1	0.14	0.01	0.1	<0.5**	<0.5**	0.9**	<5**	7.0**
	Treated		106	9.6	0.39	0.01	<0.1	9.4	2.0	1.2	<1	3.5
	Station 1		107	35	2.7	0.01	<0.1	43	2.5	<0.1	<1	4.0
	Station 2		108	33	1.8	<0.01	<0.1	42	1.8	<0.1	<1	4.0
Montreal												
	Raw	Dec. 1, 1976	49	<0.1	<0.01	<0.01	<0.01	2.3	<0.1	<0.1	<1	2.0
	Treated		50	3.7	2.5	<0.6	<0.1	6.1	2.5	0.4	<1	1.5
	Station 1		51	0.2	4.0	<1.5	<0.1	9.3	2.4	0.9	<1	3.5
	Station 2		52	3.7	3.0	<1.0	<0.1	6.6	2.6	0.5	<1	2.5
Pierrefonds												
	Raw	Dec. 2, 1976	57	6.5	0.33	<0.01	0.2	9.5**	<0.5**	<0.1**	<5**	73.0**
	Treated		58	6.4	0.34	<0.01	<0.1	7.5**	<0.5**	<0.1**	<1**	20.5**
	Station 1		59	7.2	0.38	<0.01	<0.1	11	<0.1	<0.1	<1	6.5
	Station 2		60	6.3	0.34	<0.01	<0.1	10	0.2	<0.1	<1	4.5
Quebec												
	Raw	Jan. 5, 1977	159	1.2	0.08	0.09	0.10	1.1	0.3	<0.1	<1	4.0
	Treated		160	5.6	0.8	0.13	0.05	6.3	0.6	<0.1	<1	3.0
	Station 1		161	14	2.8	0.57	0.05	16.0	3.2	<0.1	<1	3.0
	Station 2		162	9.1	1.3	0.40	0.51	11.0	1.5	<0.1	<1	2.5
Rimouski												
	Raw	Jan. 18, 1977	239	1.5	0.10	0.06	0.05	0.9	<0.1	<0.1	<1	6.0
	Treated		240	8.5	0.49	0.06	0.04	9.7	0.1	<0.1	<1	5.0
	Station 1		241	22	1.4	0.07	0.04	25	1.4	<0.1	<1	3.0
	Station 2		242	26	1.8	0.08	0.03	31	2.0	<0.1	<1	2.5
Rivière-du-Loup												
	Raw	Jan. 7, 1977	163	1.9	0.18	0.07	0.09	2.0	<0.1	<0.1	<1	8.5
	Treated		164	40	1.1	0.05	0.05	33	1.9	<0.1	<1	3.5
	Station 1		165	36	1.4	0.10	0.05	39	2.5	<0.1	<1	3.5
	Station 2		166	35	1.5	0.06	0.05	35	2.3	<0.1	<1	3.5

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
QUEBEC (Cont'd)												
St-Eustache												
	Raw	Dec. 15, 1976	123	<0.1	0.02	<0.01	<0.1	2.4	<0.1	<0.1	<1	10.0
	Treated		124	26	1.2	<0.01	<0.1	36	1.8	<0.1	<1	5.5
	Station 1		125	29	1.2	<0.01	<0.1	38	1.7	<0.1	<1	4.5
	Station 2		126	26	1.2	<0.01	<0.1	39	1.7	<0.1	<1	3.0
Shawinigan												
	Raw	Dec. 10, 1976	81	<0.1	0.04	<0.01	<0.1	<0.5**	<0.5**	<0.1**	<5**	9.5**
	Treated		82	16	0.33	<0.01	<0.1	20**	<0.5**	<0.1**	<5**	10.5**
	Station 1		83	24	0.44	<0.01	<0.1	25**	<0.5**	0.3**	<5**	10.5**
	Station 2		84	26	0.50	<0.01	0.1	30**	<0.5**	1.0**	<5**	7.0**
Sherbrooke												
	Raw	Dec. 7, 1976	109	<0.1	0.07	<0.01	<0.1	1.1	<0.1	<0.1	<1	3.0
	Treated		110	31	1.8	<0.01	<0.1	44	1.2	<0.1	<1	4.5
	Station 1		111	40	3.0	0.02	<0.1	60	4.2	<0.1	<1	4.0
	Station 2		112	34	2.8	0.01	<0.1	55	3.2	<0.1	<1	3.5
Thetford												
	Raw	Dec. 8, 1976	69	<0.1	0.08	<0.01	<0.1	8.9**	<0.5**	<0.1**	<5**	41.0**
	Treated		70	47	2.1	0.6	0.8	68**	<0.5**	<0.1**	<5**	10.0**
	Station 1		71	78	1.9	<0.01	<0.1	105**	1.8**	0.5**	<5**	36.0**
	Station 2		72	82	2.0	<0.01	<0.1	119**	0.5**	1.8**	<5**	29.5**
Trois-Rivières												
	Raw	Dec. 9, 1976	73	3.8	<0.01	<0.01	<0.1	1.5**	<0.5**	<0.1**	<5**	9.5**
	Treated		74	71	0.6	<0.01	<0.1	110	2.3	<0.1	4.5	6.0
	Station 1		75	84	3.3	<0.01	<0.1	114	2.5	<0.1	4.5	6.0
	Station 2		76	82	3.2	<0.01	<0.1	122	2.5	<0.1	4.3	4.5
Windsor												
	Raw	Dec. 7, 1976	113	1.0	0.02	0.02	0.01	<0.5	<0.1	<0.1	<1	6.5
	Treated		114	53	1.7	0.50	1.5	84	2.6	<0.1	<1	5.0
	Station 1		115	58	1.6	<0.01	0.1	79	1.1	<0.1	<1	3.5
	Station 2		116	57	1.5	<0.01	<0.1	78	2.5	<0.1	<1	3.5

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis				Direct Injection				T.O.C. mg/l
				$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	
NEW BRUNSWICK												
Bathurst												
	Raw	Jan. 8, 1977	167	0.9	0.50	0.33	0.01	<0.5	0.02	<0.1	<1	2.5
	Treated		168	6.6	1.4	0.24	0.04	5.2	1.5	<0.1	<1	1.0
	Station 1		169	13	3.8	0.60	0.05	16	4.3	0.5	<1	0.5
	Station 2		170	8.7*	2.8*	1.5*	2.4*	7.8	2.2	<0.1	<1	1.5
	Treated Repeat		168					5.7	1.3	0.4	<1	
	Station 1 Repeat		169					14	3.2	0.5	<1	
	Station 2 Repeat		170					7.9	2.1	0.8	<1	
	Station 1 Repeat		169					14	3.2	0.5	<1	
Fredericton												
	Raw	Jan. 9, 1977	171	1.3	0.30	0.28	0.22	1.5	0.3	<0.1	<1	2.0
	Treated		172	4.3	0.30	0.07	0.05	4.1	0.5	<0.1	<1	2.5
	Station 1		173	8.4	0.92	0.09	0.04	6.3	0.7	<0.1	<1	2.5
	Station 2		174	7.5	0.99	0.15	0.03	7.2	1.0	0.4	<1	4.0
	Station 1 Repeat		173					7.5	0.6	<0.1	<1	
Moncton												
	Raw	Jan. 12, 1977	195	1.1	0.05	0.03	0.03	1.3	<0.1	<0.1	<1	4.0
	Treated		196	25*	1.7	0.81*	1.8*	25	1.1	<0.1	<1	4.0
	Station 1		197	38	2.1	0.13	0.21	46	1.2	<0.1	<1	4.5
	Station 2		198	45*	3.5*	0.99*	1.8*	57	2.8	0.3	<1	4.5
Saint John												
	Raw	Jan. 11, 1977	175	1.7	0.08	0.04	0.02	1.0	<0.1	<0.1	<1	5.0
	Treated		176	31*	2.1*	0.90*	1.8*	41	1.3	<0.1	<1	5.5
	Station 1		177	32	2.0	0.12	0.24	46	2.1	0.8	<1	6.5
	Station 2		178	38*	2.3*	0.70*	1.7*	53	1.7	<0.1	<1	7.0

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis $CHCl_3$	Sparge Analysis $CHCl_2Br$	Sparge Analysis $CHClBr_2$	Sparge Analysis $CHBr_3$	Direct Injection $CHCl_3$	Direct Injection $CHCl_2Br$	Direct Injection $CHClBr_2$	Direct Injection $CHBr_3$	T.O.C. mg/l
NOVA SCOTIA												
Dartmouth												
	Raw	Jan. 15,	211	1.3	0.10	0.07	0.02	2.2	<0.1	<0.1	<1	3.5
	Treated	1977	212	9.2	0.50	0.05	0.03	11	0.1	<0.1	<1	4.0
	Station 1		213	54*	5.8*	0.84*	1.1*	75	5.5	<0.1	<1	3.5
	Station 2		214	62	5.8	0.34	0.18	88	6.6	<0.1	<1	3.5
Halifax												
	Raw	Jan. 15,	223	1.9*	0.43*	0.07*	0.59*	4	<0.1	<0.1	<1	5.0
	Treated	1977	224	26	1.3	0.11	0.10	43	0.7	<0.1	<1	8.5
	Station 1		225	39	1.8	0.11	0.11	59	1.1	<0.1	<1	7.0
	Station 2		226	52	2.3	0.09	0.12	98	3.3	<0.1	<1	7.5
Port Hawkesbury												
	Raw	Jan. 14,	203	2.0	0.16	0.12	0.15	1.0	<0.1	<0.1	<1	7.5
	Treated	1977	204	17.5*	1.9*	0.88*	1.6*	21	1.2	<0.1	<1	4.0
	Station 1		205	21.5	2.8	0.22	0.07	30	3.2	<0.1	<1	5.5
	Station 2		206	23	3.1	0.22	0.04	30	3.7	<0.1	<1	4.5
Truro												
	Raw	Jan. 14,	207	0.6	0.05	0.07	0.02	1.3	<0.1	<0.1	<1	4.5
	Treated	1977	208	2.6	0.22	0.03	0.01	3.8	<0.1	<0.1	<1	4.5
	Station 1		209	19	1.7	0.13	0.03	25	1.2	<0.1	<1	5.0
	Station 2		210	13.5	1.1	0.09	0.04	18	0.6	<0.1	<1	5.0
PRINCE EDWARD ISLAND												
Charlottetown												
	Raw	Jan. 13,	199	3.4	0.25	0.11	0.20	3.0	<0.1	<0.1	<1	0.5
	Treated	1977	200	1.5	0.28	0.44	0.51	2.0	<0.1	<0.1	<1	2.0
	Station 1		201	2.0*	1.11*	1.36*	2.5*	1.7	<0.1	<0.1	<1	1.5
	Station 2		202	1.4	0.79	1.11	2.1	1.0	<0.1	<0.1	<1	1.5

All Halomethane Values In Micrograms Per Litre

		Date of Sampling	Sample Number	Sparge Analysis				Direct Injection				T.O.C. mg/l
				$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$	
NEWFOUNDLAND												
Clarenville												
	Raw	Jan. 27,	275	2.0*	0.27*	0.32*	0.50*	1.7	<0.1	<0.1	<1	7.5
	Treated	1977	276	77	2.4	0.11	0.08	97	3.2	<0.1	<1	2.0
	Station 1		277	78	2.4	0.09	0.13	96	2.4	<0.1	<1	3.0
	Station 2		278	85	2.7	0.16	0.08	104	2.2	<0.1	<1	1.5
Grand Falls												
	Raw	Jan. 28,	279	122	2.8	0.09	0.07	140	2.7	<0.1	<1	9.5
	Treated	1977	280	3.6	0.12	0.06	0.04	7.0	.4	<0.1	<1	1.5
	Station 1		281	121*	3.5*	1.04*	1.1*	150	2.7	<0.1	<1	7.5
	Station 2		282	3.9	0.34	0.25	0.14	6.8	<0.1	<0.1	<1	9.0
St. John's												
	Raw	Jan. 29,	283	1.7	0.41	0.34	0.39	2.6	<0.1	<0.1	<1	3.5
	Treated	1977	284	4.5	0.93	0.47	0.18	11	1.2	0.3	<1	3.0
	Station 1		285	23	6.4	1.6	0.16	34	8.4	1.4	<1	4.0
	Station 2		286	14	5.7	1.8	0.19	23	5.7	1.5	<1	5.0

* These samples are suspected to be contaminated from standards, containing high levels of halomethanes, run immediately before these samples.

** Sample bottles cracked on storage, T.O.C. values are suspect and halomethane levels are those found by analysis on the SE-30 column.

REPLICATE PEAK AREAS FOR STANDARD 3A, DIRECT INJECTION

PEAK AREA UNITS

Date	Run	$CHCl_3$ (45.5 ppb)	$CHCl_2Br$ (17.5 ppb)	$CHClBr_2$ (14.7 ppb)	$CHBr_3$ (17.3 ppb)
Jan. 22	8	36,080	36,810	32,580	19,490
Jan. 22	9	34,280	42,600	28,520	19,310
Jan. 22	18	32,960	39,960	28,430	20,820
Jan. 22	25	33,330	42,850	30,210	21,500
Jan. 22	34	33,700	41,730	29,770	19,550
Jan. 23	43	35,390	40,130	26,780	18,450
Jan. 23	44	36,650	40,740	27,080	18,960
Jan. 23	58	35,900	41,870	28,280	20,630
Jan. 23	65	34,820	39,560	28,120	20,670
Jan. 24	71	34,760	40,050	27,600	20,660
Jan. 25	80	34,050	40,740	27,060	18,430
Feb. 1	3	34,980	49,690	33,620	22,370
Feb. 1	2	35,950	51,310	33,630	22,150
Feb. 1	8	36,590	50,540	33,140	21,880
Feb. 2	10	36,650	52,390	35,220	22,761
Feb. 2	12	36,680	53,110	34,920	23,620
Feb. 2	21	37,050	53,910	35,050	21,440
Feb. 2	30	36,000	50,330	32,250	21,640
Feb. 3	36	36,280	52,030	33,500	21,910
Feb. 3	42	37,910	54,960	36,190	20,920
Feb. 3	53	38,610	55,810	36,400	22,750
Feb. 9	43	36,280	52,030	33,500	21,910
Feb. 9	72	38,360	45,710	31,040	23,260
Feb. 9	81	39,340	44,730	30,200	22,870
Feb. 10	89	38,090	45,090	30,390	23,440
Feb. 10	109	39,040	46,490	30,060	23,690
Feb. 10	120	41,250	44,920	30,020	23,020
Feb. 10	129	39,430	44,970	30,230	23,490
Feb. 11	147	39,870	410	30,080	23,340
Feb. 11	167	38,650	45,490	29,610	22,640
Feb. 11	176	38,820	45,070	29,060	22,770
Feb. 14	186	39,190	51,460	32,030	23,310
Feb. 14	195	40,090	50,550	30,860	22,560
Feb. 16	228	36,660	51,520	32,920	22,370

REPLICATE PEAK AREAS FOR STANDARD 3A, SPARGE

PEAK AREA UNITS X 1000

Date	Run	$CHCl_3$ (45.5 ppb)	$CHCl_2Br$ (17.5 ppb)	$CHClBr_2$ (14.7 ppb)	$CHBr_3$ (17.3 ppb)
Jan. 16	758	8,708	14,640	8,356	1,958
Jan. 16	770	8,948	15,070	8,628	2,199
Jan. 17	781	8,746	14,920	8,226	2,023
Jan. 17	791	9,100	14,800	7,756	1,735
Jan. 17	796	8,944	15,310	8,514	2,046
Jan. 17	803	9,076	15,090	7,980	1,792
Jan. 17	806	9,342	15,070	7,936	1,743
Jan. 17	810	8,648	16,900	8,944	2,113
Jan. 20	820	10,440	20,500	10,440	22,085
Jan. 20	825	10,040	20,430	11,010	2,316
Jan. 20	835	9,670	20,120	11,110	2,427
Jan. 21	842	9,570	19,640	10,370	2,150
Jan. 21	847	9,368	16,900	10,360	2,780
Jan. 21	855	9,586	16,730	9,580	2,387
Jan. 21	866	8,764	15,150	8,710	2,168
Jan. 22	874	9,004	15,660	9,046	2,249
Jan. 28	86	9,288	16,630	9,892	2,744
Jan. 28	94	8,974	16,480	10,310	2,945
Jan. 28	101	8,732	15,270	8,892	2,272
Jan. 29	108	8,808	15,400	8,962	2,286
Jan. 31	113	8,648	17,480	10,460	2,517
Jan. 31	120	8,632	17,810	10,960	2,730
Feb. 4	2	9,894	19,970	11,250	2,631
Feb. 7	14	9,060	16,890	11,220	3,602
Feb. 8	29	9,800	18,120	11,490	3,366

HEALTH AND WELFARE GAS SPARGE DATA FOR DISTRIBUTION SYSTEM (Station 1)

CONCENTRATION OF HALOMETHANES (ppb)

LOCATION	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
BRITISH COLUMBIA				
Dawson Creek	15	-	-	-
Kamloops	25	-	-	-
Kelowna	26	1.8	-	-
Nanaimo	5	-	-	-
Penticton	54	-	-	-
Prince George	<1	-	-	-
Vancouver no. 1	6	-	-	-
Vancouver no. 2	11	-	-	-
Victoria	7	-	-	-
ALBERTA				
Calgary	4	0.7	-	-
Edmonton	5	<<1		
Grand Prairie	52	<1		
High Prairie	2	-	-	-
Lethbridge	<1	-	-	-
Medicine Hat	9	2.2	-	-
Vermillion	2	<1	-	-
SASKATCHEWAN				
Prince Albert	<<1	-	-	-
Regina	53	4.5	6.5	-
Saskatoon	11	1.8	-	-
Swift Current	41	9.3	1.0	-
Yorkton	1	0.9	-	-
MANITOBA				
Brandon	14	3.8	<0.5	-
Portage La Prairie	2	-	-	-
Selkirk	<1	-	-	-
Swan River	5	0.6	-	-
Winnipeg	62	4.4	-	-
ONTARIO				
Barrie	1	<<1	-	-
Belleville	48	5.1	-	-
Brantford	73	12	0.8	-
Cayuga	72	15	1.4	-
Niagara-on-the-Lake	6	4.8	1.4	-
Ottawa (18-11-76)	40	1.1	-	-
Smiths Falls (18-11-76)	30	2.1	-	-
Sudbury	42	1.3	-	-
Thunder Bay	4	0.9	-	-
Toronto	5	3.5	1.3	-
Windsor	5	5.1	2.0	-

HEALTH AND WELFARE GAS SPARGE DATA FOR DISTRIBUTION SYSTEM (Station 1)

CONCENTRATION OF HALOMETHANES (ppb)

LOCATION	$CHCl_3$	$CHCl_2Br$	$CHClBr_2$	$CHBr_3$
QUEBEC				
Cap-de-la-Madeleine	<<1	-	-	-
Drummondville	7	-	-	-
Granby	<<1	-	-	-
Hudson	<<1	-	-	-
Lachine	3	0.6	-	-
Laval	11	0.5	-	-
Levis	3	0.6	-	-
Longueuil	7	5.2	1.5	-
Montreal	4	3.4	1.1	-
Magog	32	1.9	-	-
Hull	51	1.3	-	-
Pierrefonds	5	1	-	-
Quebec	9	2.5	-	-
Rimouski	3	0.8	-	-
Rivière-du-Loup	30	1.3	-	-
Shawinigan	19	0.3	-	-
Sherbrooke	34	2.2	-	-
St. Eustache	23	1.1	-	-
Thetford Mines	83	1.3	-	-
Trois Rivières	81	1.0		
Windsor	51	0.9	-	-
NEW BRUNSWICK				
Bathurst	9	3.3	0.9	-
Fredericton	4	0.8	-	-
Moncton	32	1.6		
Saint John	28	1.7	-	-
NOVA SCOTIA				
Dartmouth	54	5.5	<<1	-
Halifax	40	1.6	-	-
Port Hawkesbury	22	3.0	-	-
Truro	16	1.5		
PRINCE EDWARD ISLAND				
Charlottetown	<1	-	-	-
NEWFOUNDLAND				
Clarenville	65	2.4	-	-
Grand Falls	2	-	-	-
St. John's	22	5.6	<1	-

APPENDIX 3

TOTAL ORGANIC CARBON ANALYSIS
UNIVERSITY OF TORONTO

Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l	Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l
1	4.5	1.5	3.0	37	47.0	45.0	2.0
2	5.0	1.5	3.5	38	168.0	156.0	12.0
3	5.5	1.5	4.0	39	49.0	45.5	3.5
4	5.0	1.0	4.0	40	49.5	46.0	3.5
5	29.5	25.0	4.5	41	23.0	14.5	8.5
6	28.0	23.5	4.5	42	13.5	10.0	3.5
7	28.0	23.5	4.5	43	15.5	11.0	4.5
8	26.5	23.5	3.0	44	14.5	10.5	4.0
9	35.0	24.5	10.5	45	29.0	23.0	6.0
10	30.0	23.0	7.0	46	25.0	20.5	4.5
11	29.5	23.0	6.5	47	27.5	21.0	6.5
12	29.5	22.5	7.0	48	26.0	21.0	5.0
13	39.0	23.0	16.0	49	27.0	25.0	2.0
14	98.0	70.0	28.0	50	27.0	25.5	1.5
15	43.0	30.5	12.5	51	27.5	24.0	3.5
16	37.5	25.0	12.5	52	26.5	24.0	2.5
17	17.0	7.5	9.5	53	17.5	9.0	8.5
18	11.0	7.5	3.5	54	13.0	9.0	4.0
19	12.0	7.5	4.5	55	36.0	17.0	19.0
20	14.5	7.0	7.5	56	48.0	23.5	24.5
21	38.0	31.0	7.0	57	105.5	32.5	73.0
22	59.5	55.0	4.5	58	30.0	9.5	20.5
23	60.0	56.0	4.0	59	14.0	7.5	6.5
24	60.0	54.0	6.0	60	12.5	8.0	4.5
25	22.5	19.0	3.5	61	no sample	----------	
26	23.0	20.0	13.5	62	38.0	36.5	1.5
27	22.0	19.5	2.5	63	38.5	36.0	2.5
28	22.0	20.5	1.5	64	38.0	35.5	2.5
29	60.0	54.5	5.5	65	15.0	6.5	8.5
30	56.5	52.0	4.5	66	12.0	6.0	6.0
31	56.0	52.0	4.0	67	13.5	6.5	7.0
32	54.5	51.5	3.0	68	12.5	6.5	6.0
33	26.0	24.0	2.0	69	56.0	15.0	41.0
34	28.0	26.0	2.0	70	13.0	3.0	10.0
35	26.0	26.0	0	71	46.0	10.0	36.0
36	27.5	26.0	1.5	72	34.5	5.0	29.5

Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l
73	13.0	3.5	9.5
74	9.0	3.0	6.0
75	9.0	3.0	6.0
76	8.0	3.5	4.5
77	---------- no sample ----------		
78	6.0	5.5	0.5
79	7.0	6.0	1.0
80	7.0	6.5	0.5
81	13.5	4.0	9.5
82	13.0	2.5	10.5
83	13.0	2.5	10.5
84	9.0	2.0	7.0
85	13.0	6.0	7.0
86	8.5	5.0	3.5
87	7.5	5.0	2.5
88	7.5	5.0	2.5
89	13.5	11.5	2.0
90	13.5	11.5	2.0
91	13.0	12.0	1.0
92	13.5	12.0	1.5
93	32.0	22.5	9.5
94	32.0	21.5	10.5
95	31.0	22.0	9.0
96	31.0	22.0	9.0
97	122.0	122.0	0
98	40.5	38.5	2.0
99	41.0	40.5	0.5
100	30.0	27.5	2.5
101	16.5	8.0	8.5
102	12.0	10.0	2.0
103	19.0	18.5	0.5
104	12.5	10.0	2.5
105	15.5	8.5	7.0
106	9.0	5.5	3.5
107	15.0	11.0	4.0
108	15.0	11.0	4.0
109	14.0	11.0	3.0
110	15.5	11.0	4.5
111	15.0	11.0	4.0
112	14.0	10.5	3.5
113	---------- to follow ----------		
114	10.0	5.0	5.0
115	8.5	5.0	3.5
116	8.5	5.0	3.5
117	15.0	7.0	8.0
118	15.0	11.0	4.0
119	15.0	10.0	5.0
120	14.5	10.0	4.5
121	2.5	1.5	1.0
122	2.5	1.5	1.0
123	17.5	7.5	10.0
124	13.0	7.5	5.5
125	12.5	8.0	4.5
126	12.0	9.0	3.0
127	84.0	75.0	9.0
128	17.0	10.5	6.5
129	17.0	11.5	5.5
130	18.0	13.5	4.5
131	73.5	62.5	11.0
132	28.0	22.5	5.5
133	29.5	20.0	9.5
134	29.0	20.0	9.0
135	78.0	71.5	6.5
136	77.0	72.0	5.0
137	77.0	72.0	5.0
138	78.0	72.0	6.0
139	51.0	42.0	9.0
140	46.5	38.5	8.0
141	46.5	38.0	8.5
142	66.0	58.0	8.0
143	91.0	88.5	2.5
144	94.5	92.0	2.5
145	100.0	97.0	3.0
146	100.5	97.0	3.5
147	37.5	36.0	1.5
148	39.0	37.0	2.0
149	38.0	37.0	1.0
150	38.5	37.0	1.5
151	37.5	35.0	2.5
152	18.0	16.0	2.0
153	17.5	16.0	1.5
154	18.0	16.5	1.5
155	25.0	19.5	5.5
156	--------- no sample ----------		
157	22.0	18.0	4.0
158	22.0	17.5	4.5
159	9.5	5.5	4.0
160	11.0	8.0	3.0
161	10.5	7.5	3.0
162	10.5	8.0	2.5
163	15.5	7.0	8.5
164	12.0	8.5	3.5
165	12.0	8.5	3.5
166	12.0	8.5	3.5
167	24.5	22.0	2.5
168	21.0	20.0	1.0
169	19.0	18.5	0.5
170	20.0	18.5	1.5
171	18.0	16.0	2.0
172	17.5	15.0	2.5
173	17.5	15.0	2.5
174	19.0	15.0	4.0
175	8.0	3.0	5.0
176	8.0	2.5	5.5

Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l	Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l
177	8.5	2.0	6.5	217	11.5	10.5	1.0
178	9.0	2.0	7.0	218	11.5	10.5	1.0
179	62.0	59.5	2.5	219	158.0	152.0	6.0
180	64.0	59.0	5.0	220	154.0	145.0	9.0
181	60.5	59.0	1.5	221	145.0	134.0	11.0
182	59.0	57.5	1.5	222	149.0	133.0	16.0
183	45.0	44.0	1.0	223	7.0	2.0	5.0
184	45.0	42.0	3.0	224	10.0	1.5	8.5
185	46.5	43.5	3.0	225	8.5	1.5	7.0
186	46.0	43.0	3.0	226	9.0	1.5	7.5
187	48.0	46.0	2.0	227	144.0	96.0	48.0
188	45.5	45.0	0.5	228	102.5	75.5	27.0
189	47.0	45.0	2.0	229	102.0	76.0	26.0
190	47.5	44.5	3.0	230	102.0	75.0	27.0
191	42.5	41.0	1.5	231	44.5	43.0	1.5
192	43.0	41.5	1.5	232	44.0	40.5	3.5
193	41.5	41.0	0.5	233	44.0	40.0	4.0
194	44.0	41.0	3.0	234	46.0	40.0	6.0
195	6.0	2.0	4.0	235	69.5	64.0	5.5
196	6.0	2.0	4.0	236	40.5	33.5	7.0
197	6.5	2.0	4.5	237	45.0	40.0	5.0
198	6.5	2.0	4.5	238	44.5	38.5	6.0
199	25.5	25.0	0.5	239	33.0	27.0	6.0
200	29.0	27.0	2.0	240	32.0	27.0	5.0
201	28.5	27.0	1.5	241	30.0	27.0	3.0
202	28.5	27.0	1.5	242	30.0	27.5	2.5
203	9.5	2.0	7.5	243	---------- no sample ----------		
204	6.0	2.0	4.0	244	23.5	22.0	1.5
205	8.0	2.5	5.5	245	22.5	21.5	1.0
206	7.0	2.5	4.5	246	23.0	23.0	0.0
207	6.0	1.5	4.5	247	11.5	10.0	1.5
208	6.0	1.5	4.5	248	11.5	10.0	1.5
209	6.5	1.5	5.0	249	10.5	10.0	0.5
210	6.0	1.0	5.0	250	11.5	10.0	1.5
211	6.5	3.0	3.5	251	27.5	27.5	0
212	6.5	2.5	4.0	252	30.0	28.0	2.0
213	6.0	2.5	3.5	253	29.5	28.0	1.5
214	6.0	2.5	3.5	254	29.0	28.0	1.0
215	32.5	31.5	1.0	255	12.0	5.0	7.0
216	13.0	11.0	2.0	256	11.0	4.5	6.5

Sample No.	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l
257	11.0	4.5	6.5
258	11.0	5.0	6.0
259	5.0	2.0	3.0
260	5.0	2.0	3.0
261	5.0	2.0	3.0
262	7.0	2.0	5.0
263	5.0	2.0	3.0
264	5.0	2.0	3.0
265	4.5	1.5	3.0
266	4.5	1.5	3.0
267	7.0	3.5	3.5
268	7.5	3.5	4.0
269	8.0	4.0	4.0
270	7.0	5.0	2.0
271	6.0	3.0	3.0
272	6.0	3.0	3.0
273	6.5	3.0	3.5
274	6.0	3.0	3.0
275	8.5	1.0	7.5
276	10.0	8.0	2.0
277	10.0	7.0	3.0
278	10.0	8.5	1.5
279	13.0	3.5	9.5
280	45.5	44.0	1.5
281	13.0	5.5	7.5
282	11.0	2.0	9.0
283	4.5	1.0	3.5
284	4.0	1.0	3.0
285	5.0	1.0	4.0
286	6.0	1.0	5.0
287			
288			

Sample No. *	Total Carbon mg/l	Inorganic Carbon mg/l	Organic Carbon mg/l
13	30.0	25.5	4.5
14	29.0	24.0	5.0
15	30.5	25.5	5.0
16	29.0	24.5	4.5
17	16.5	7.0	9.5
18	11.0	7.0	4.0
19	10.0	7.0	3.0
20	11.0	7.5	3.5
113a	11.5	5.0	6.5

* Resampled

APPENDIX 4

FREQUENCY DISTRIBUTIONS

APPENDIX 4

FREQUENCY DISTRIBUTIONS

1.0 GAS SPARGE

1.1 Raw Water

Figure 1.1.1 $CHCl_3$
1.1.2 $CHCl_2Br$
1.1.3 $CHClBr_2$
1.1.4 $CHBr_3$

1.2 Treated Water

Figure 1.2.1 $CHCl_3$
1.2.2 $CHCl_2Br$
1.2.3 $CHClBr_2$
1.2.4 $CHBr_3$

1.3 Station 1

Figure 1.3.1 $CHCl_3$
1.3.2 $CHCl_2Br$
1.3.3 $CHClBr_2$
1.3.4 $CHBr_3$

1.4 Station 2

Figure 1.4.1 $CHCl_3$
1.4.2 $CHCl_2Br$
1.4.3 $CHClBr_2$
1.4.4 $CHBr_3$

2.0 DIRECT INJECTION

2.1 Raw Water

Figure 2.1.1 $CHCl_3$
2.1.2 $CHCl_2Br$
2.1.3 $CHClBr_2$

2.2 Treated Water

Figure 2.2.1 $CHCl_3$
2.2.2 $CHCl_2Br$
2.2.3 $CHClBr_2$

2.3 Station 1

Figure 2.3.1 $CHCl_3$
2.3.2 $CHCl_2Br$
2.3.3 $CHClBr_2$

2.4 Station 2

Figure 2.4.1 $CHCl_3$
2.4.2 $CHCl_2Br$
2.4.3 $CHClBr_2$

FIGURE 1.1.1

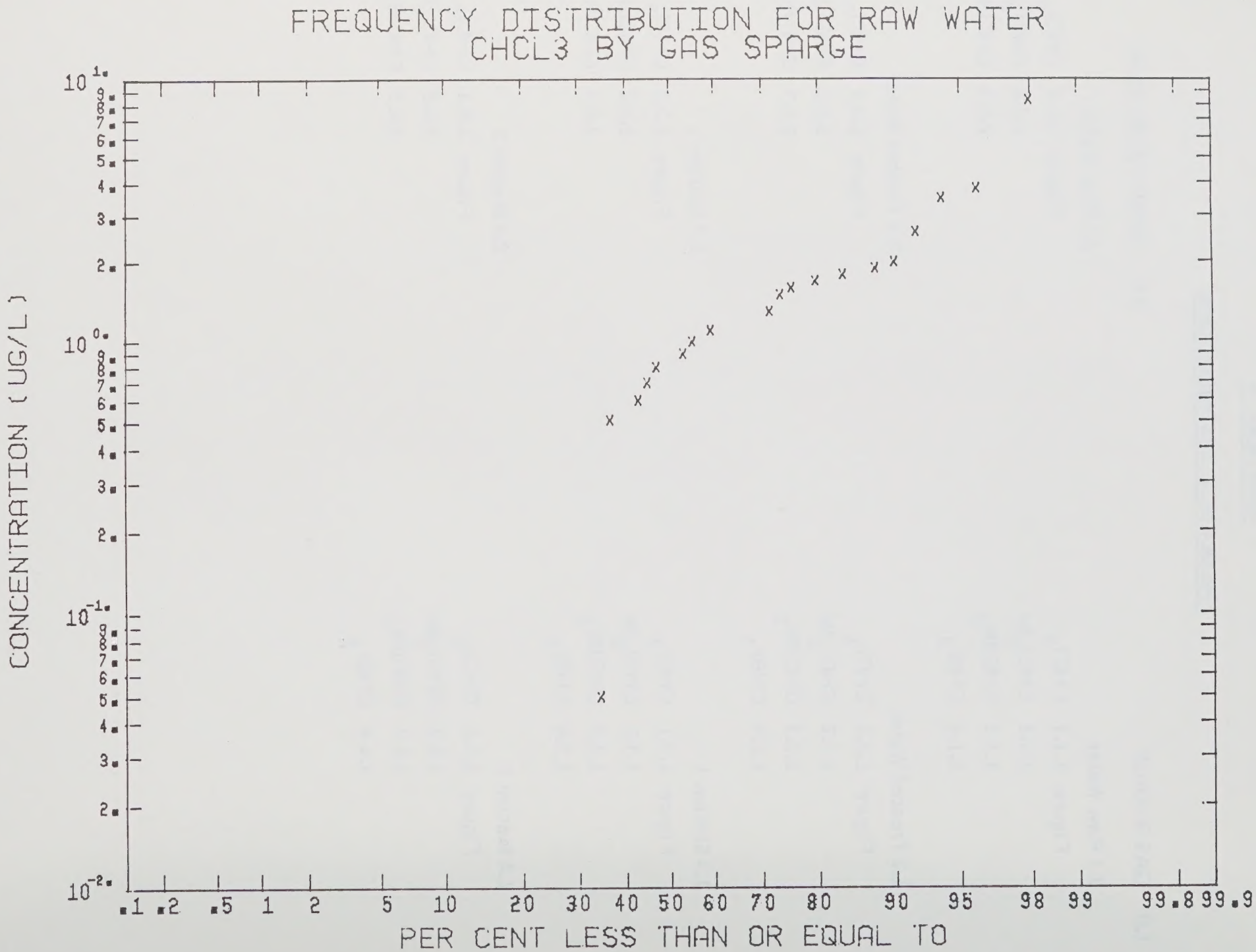

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCL3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
10^1.
10^0.
10^-1.
10^-2.
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.1.2

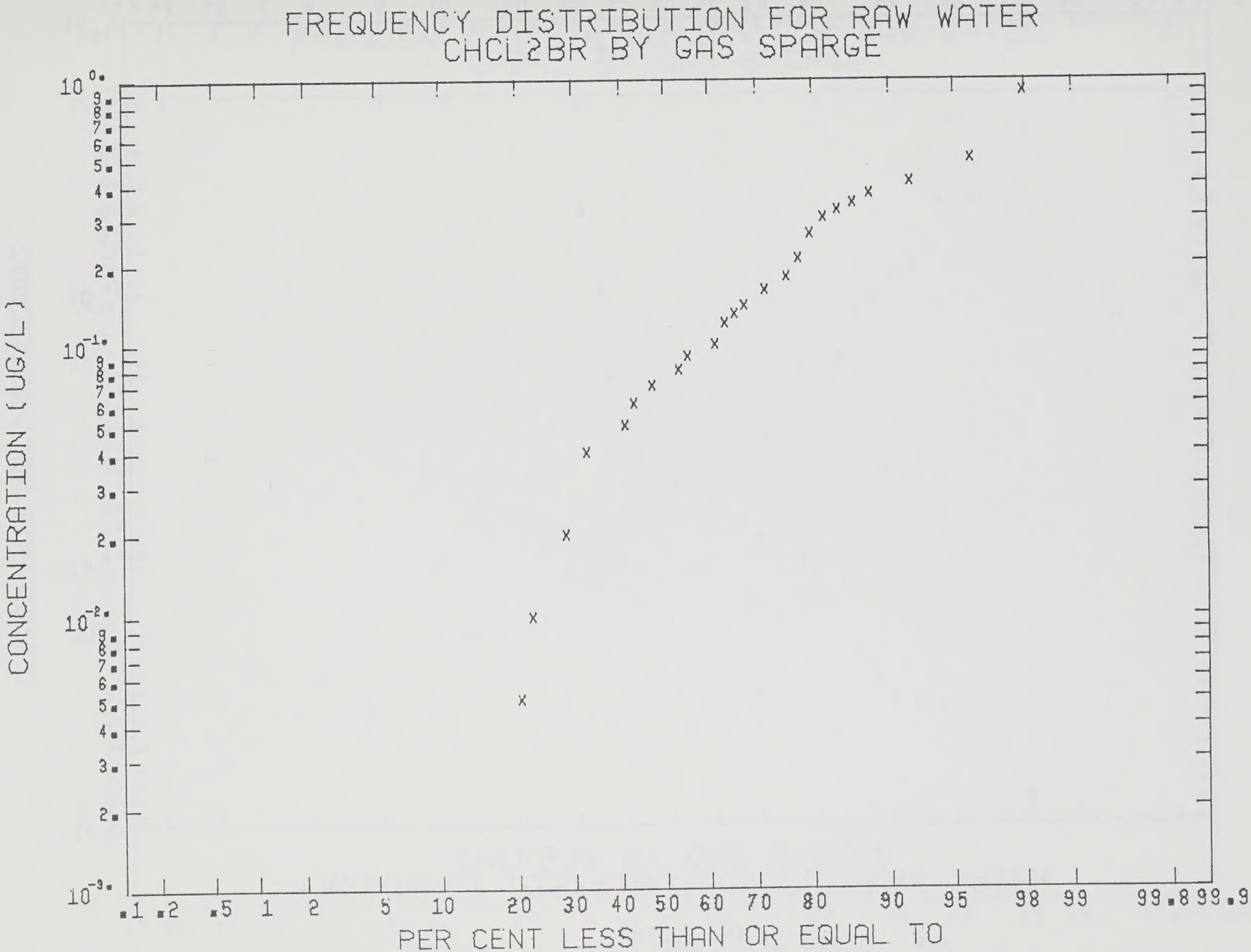

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCL2BR BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.1.3

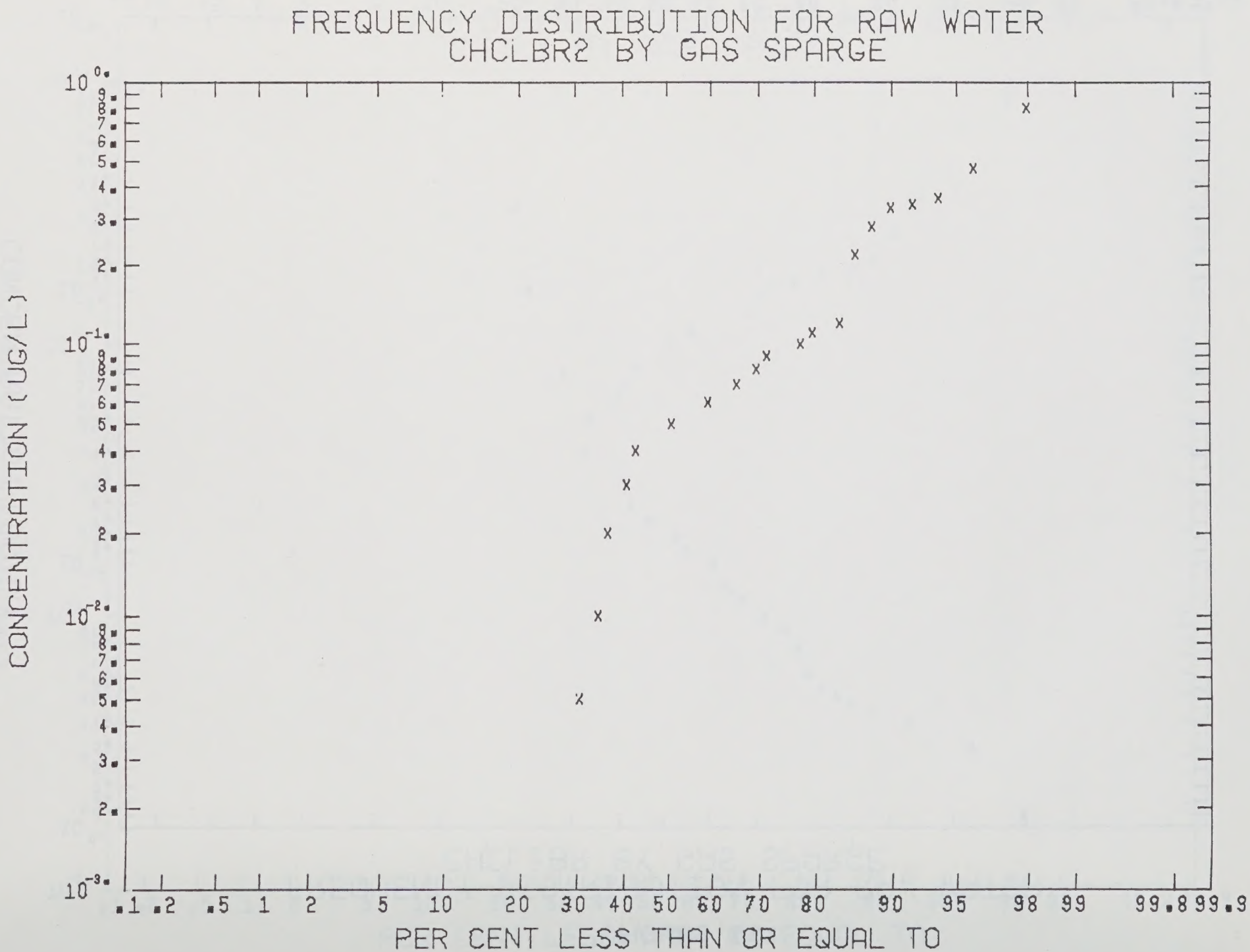

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCLBR2 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.1.4

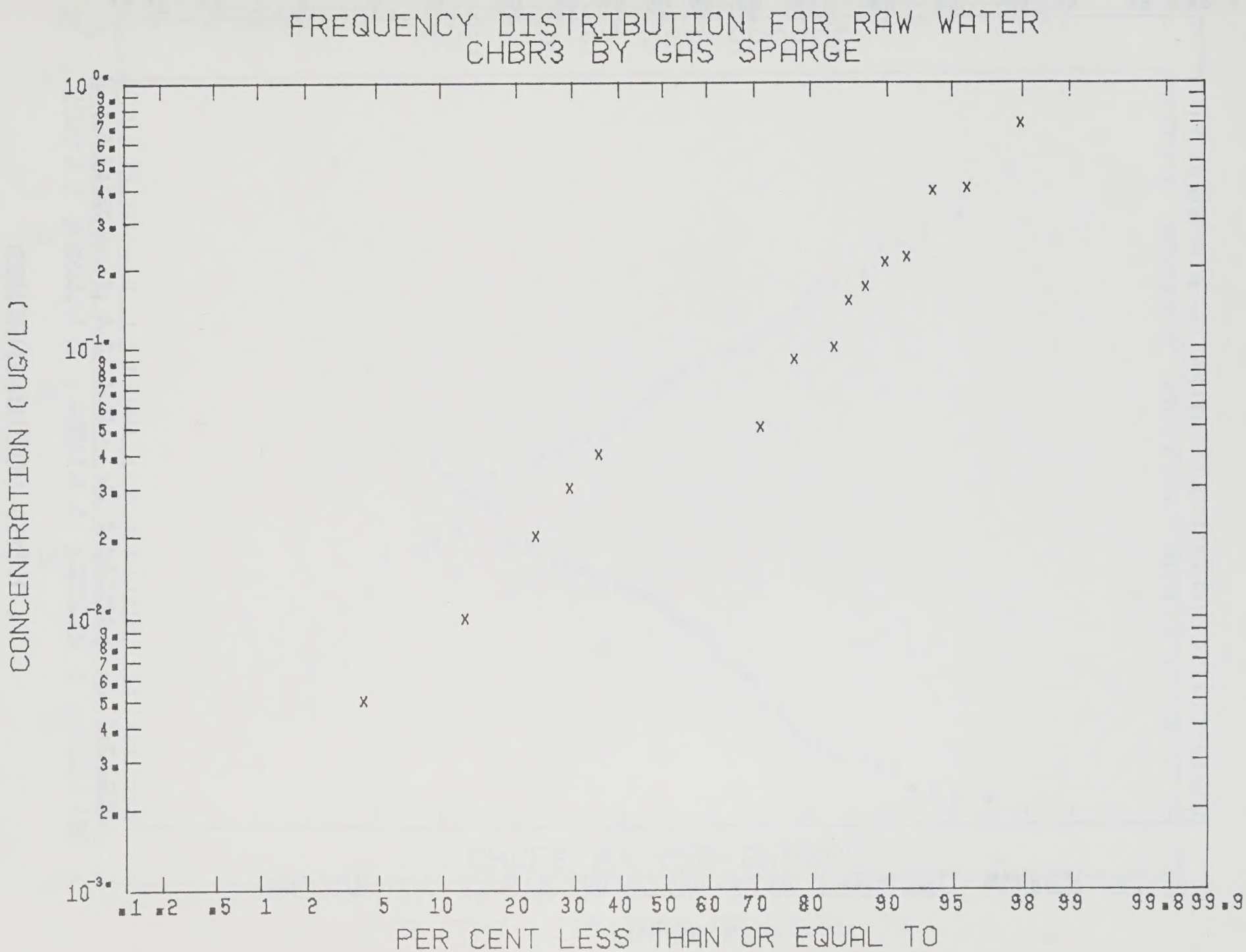

FREQUENCY DISTRIBUTION FOR RAW WATER
CHBR3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.2.1

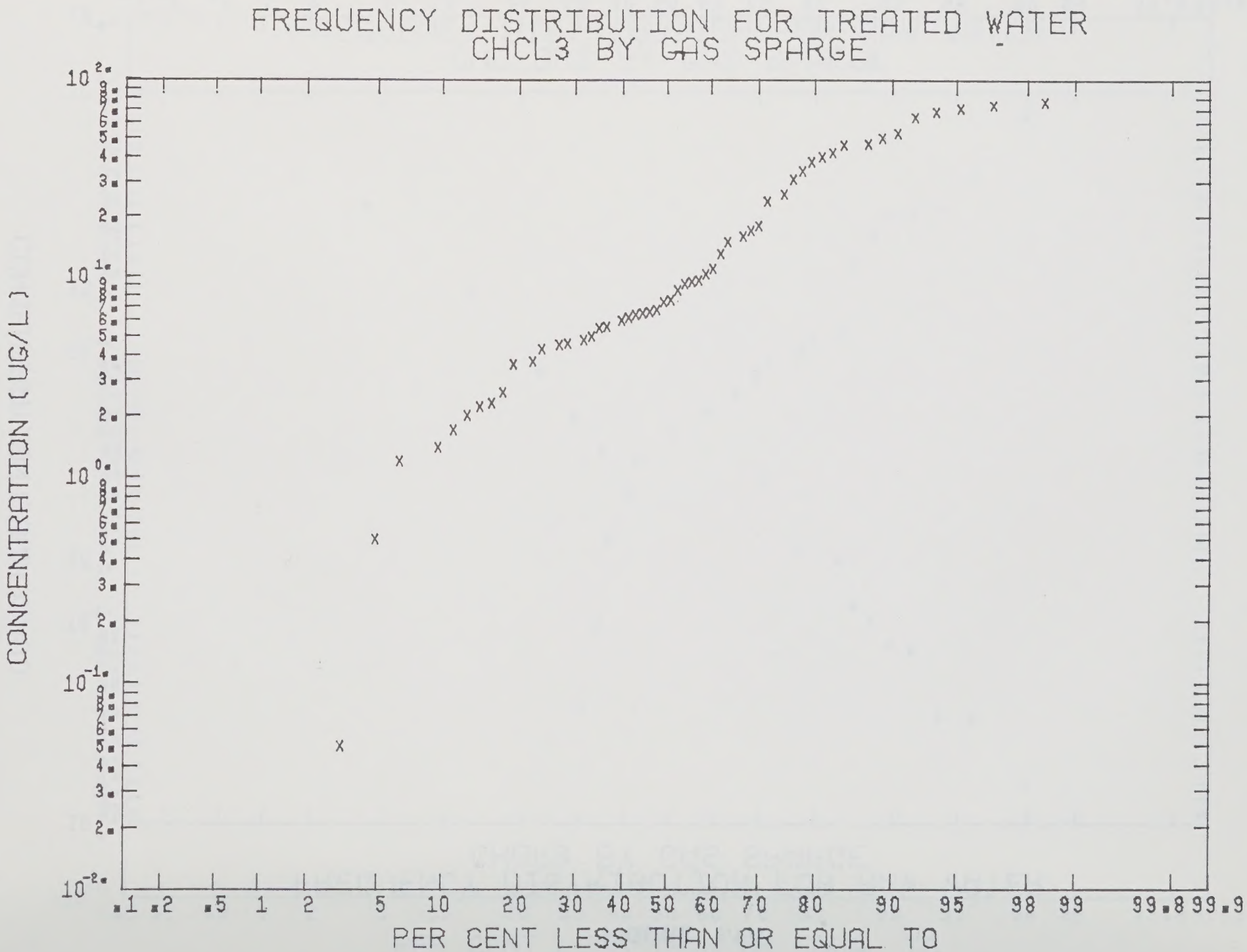

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCL3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.2.2

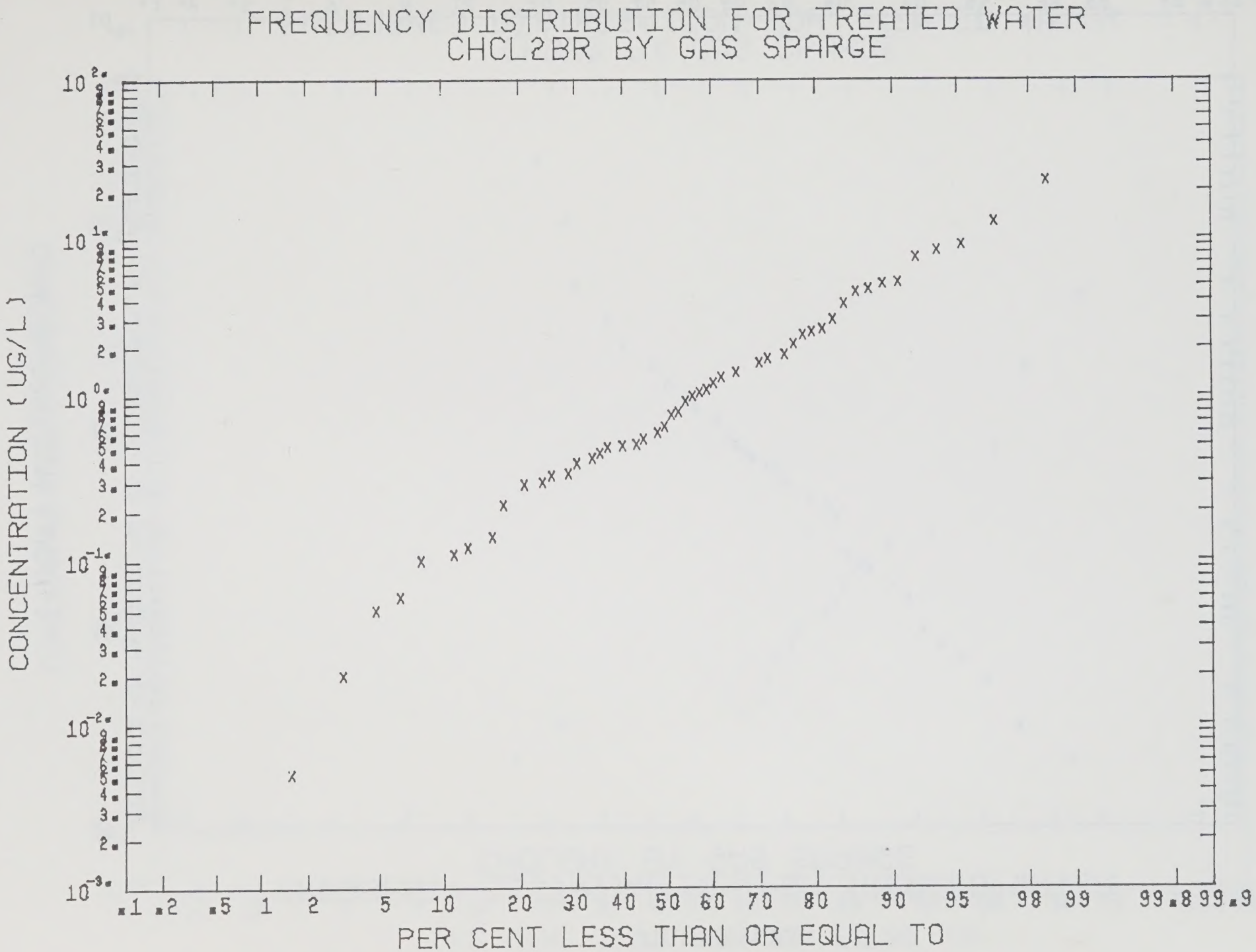

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCL2BR BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.2.3

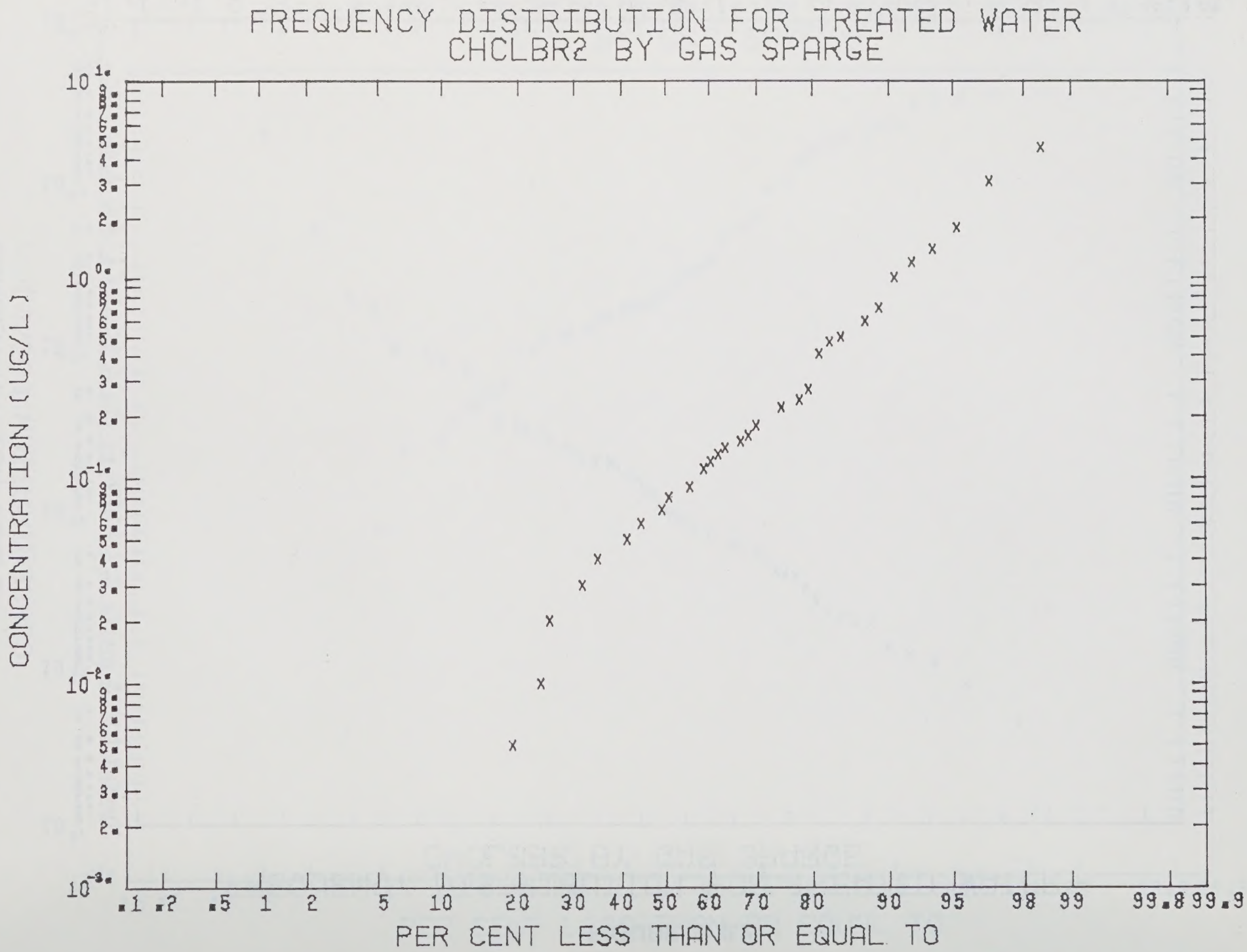

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCLBR2 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.2.4

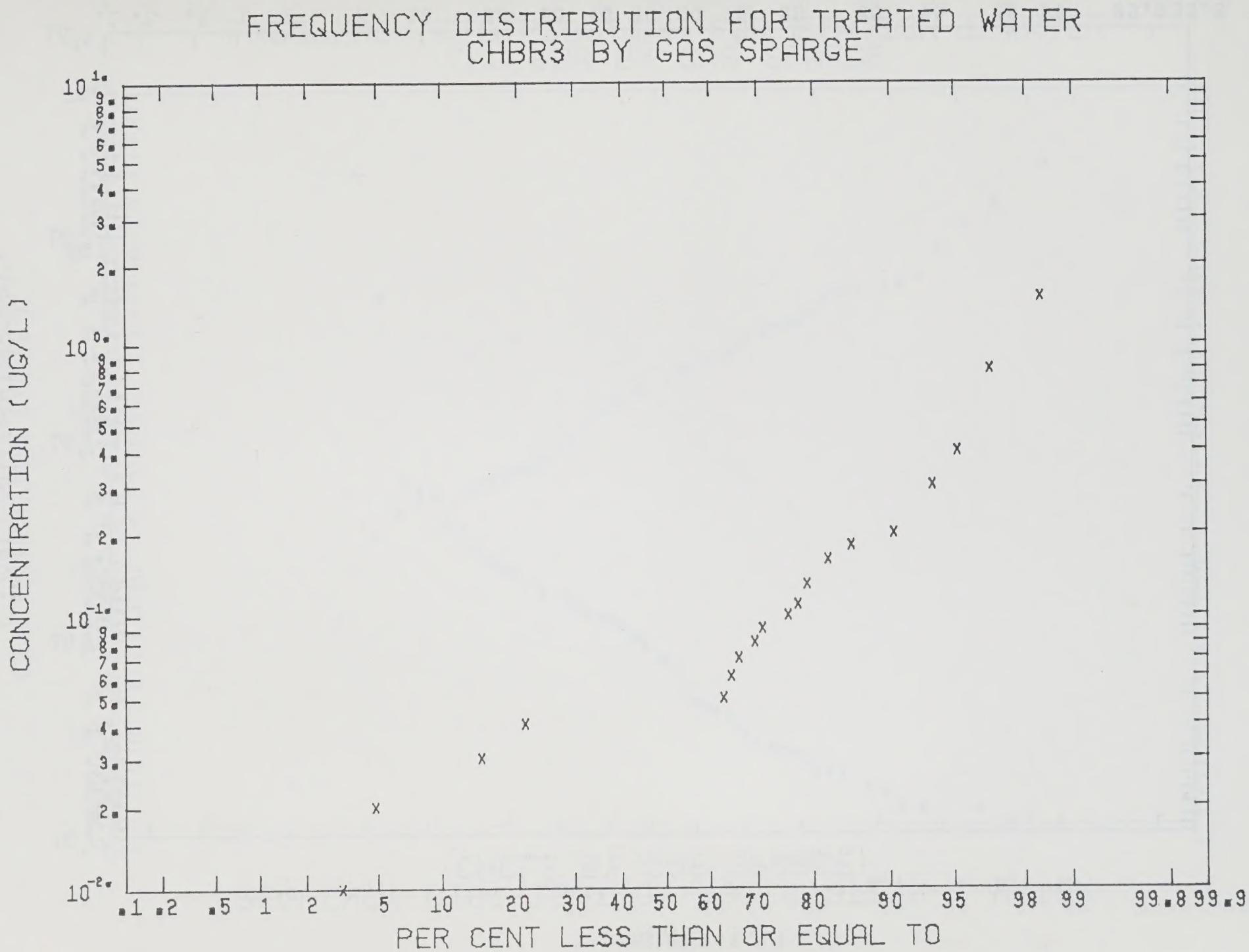

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHBR3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.3.1

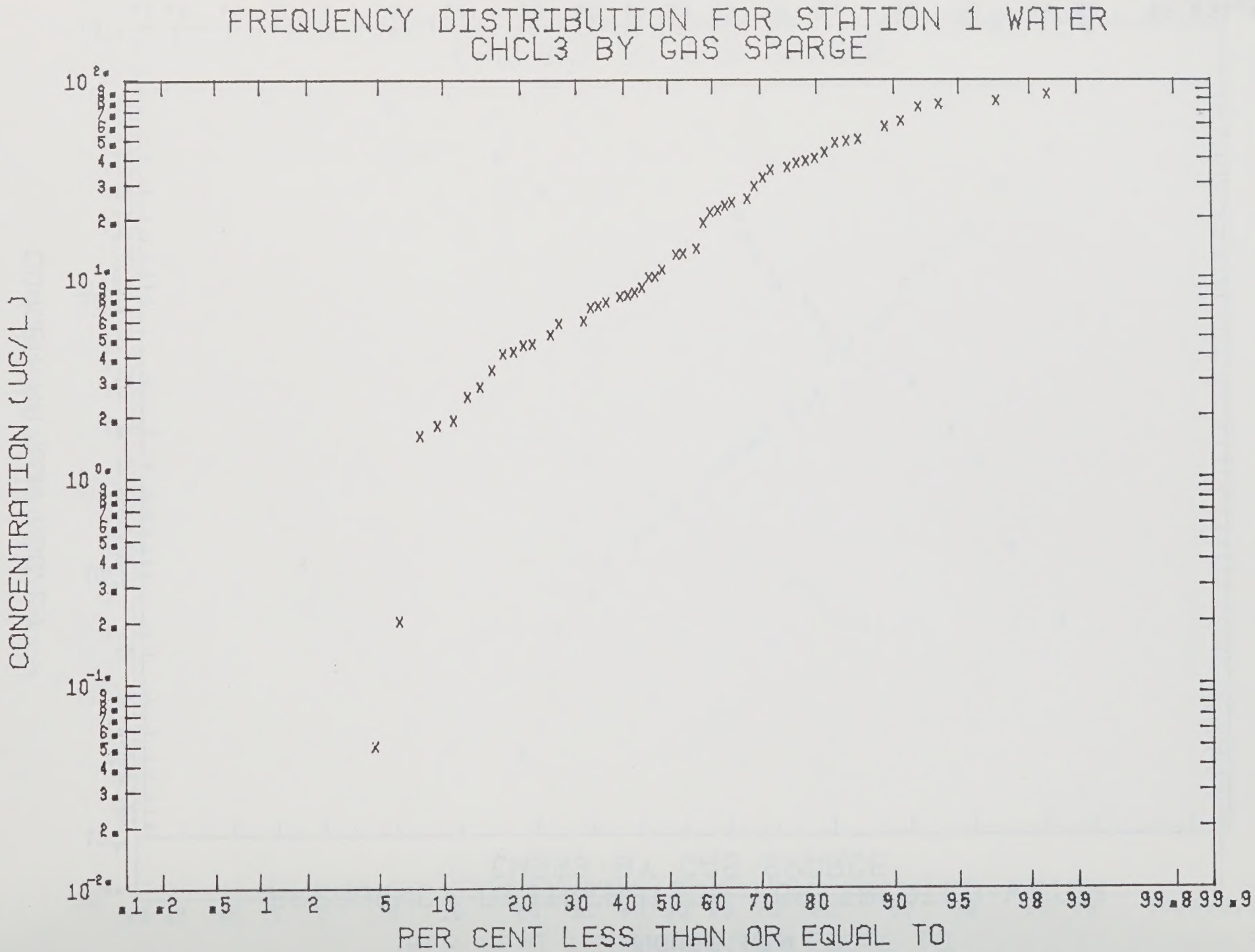

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCL3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.3.2

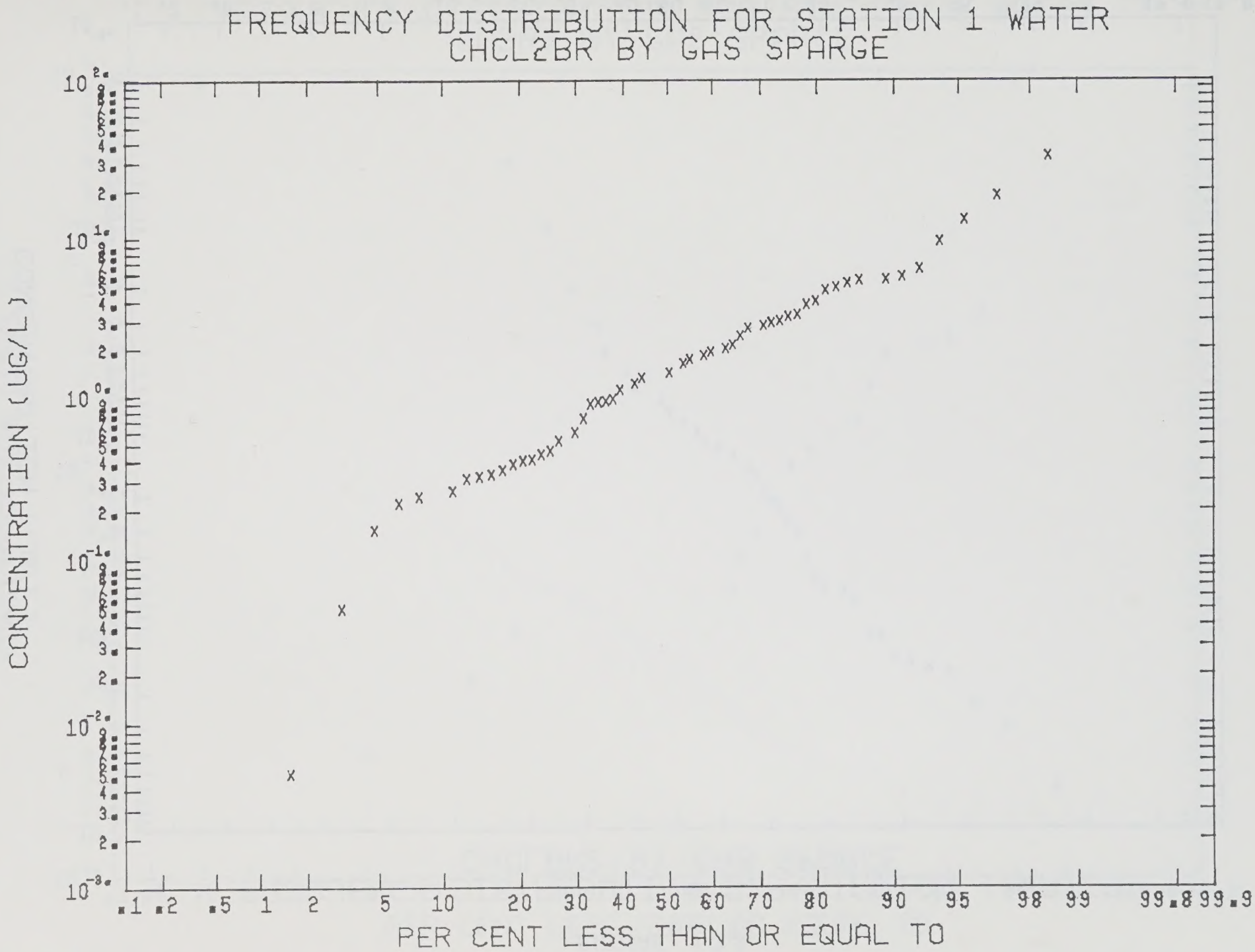

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCL2BR BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.3.3

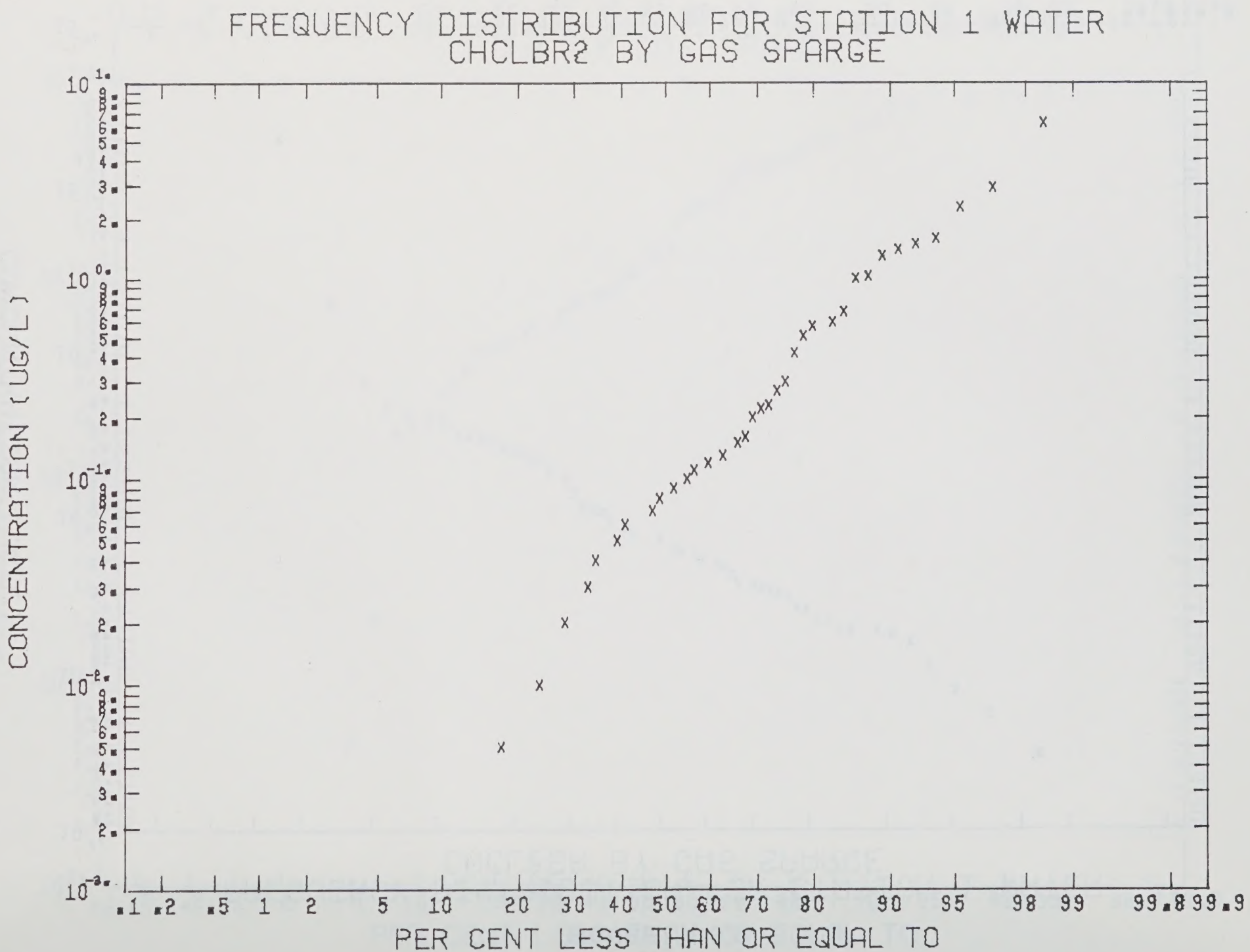

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCLBR2 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.3.4

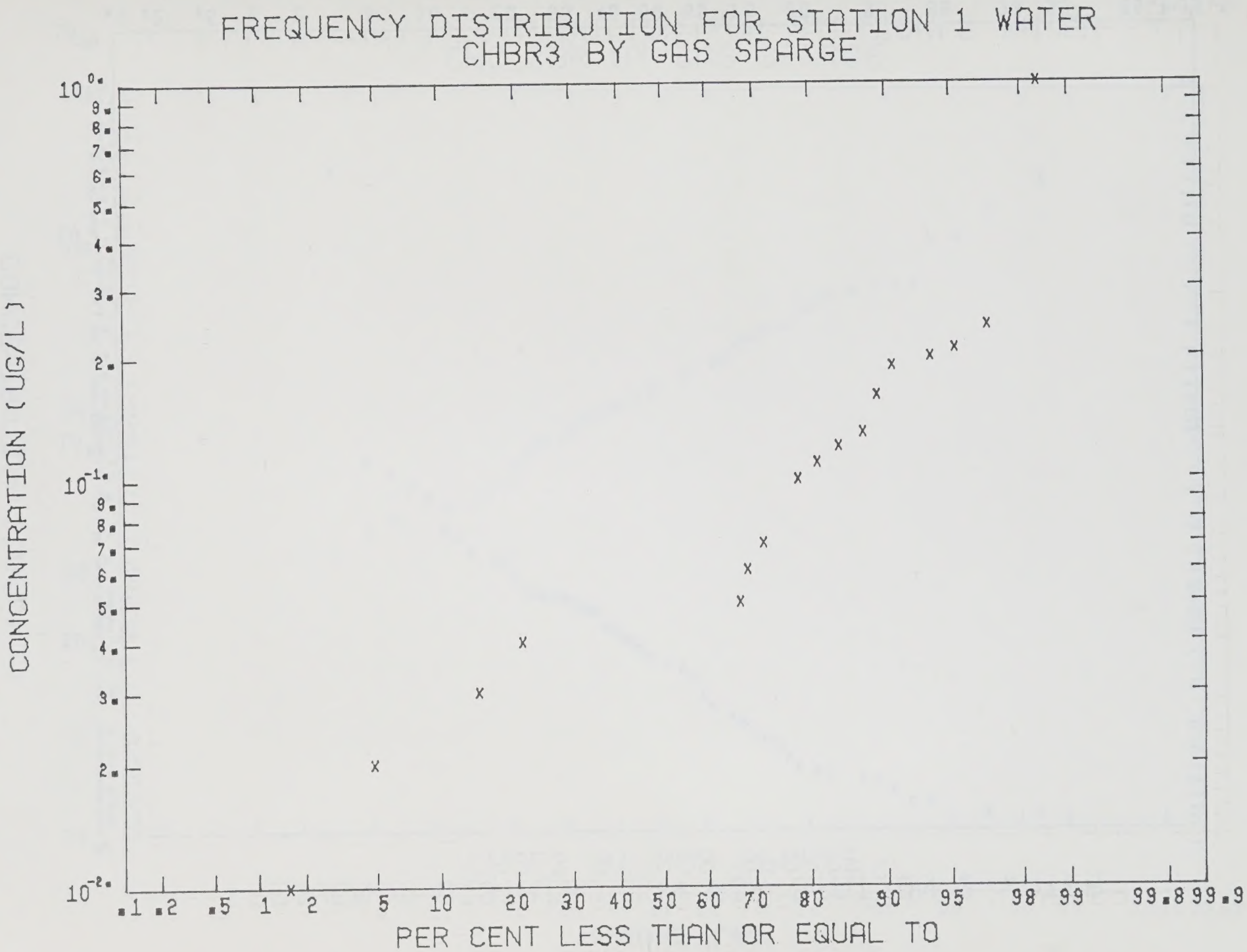

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHBR3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 1.4.1

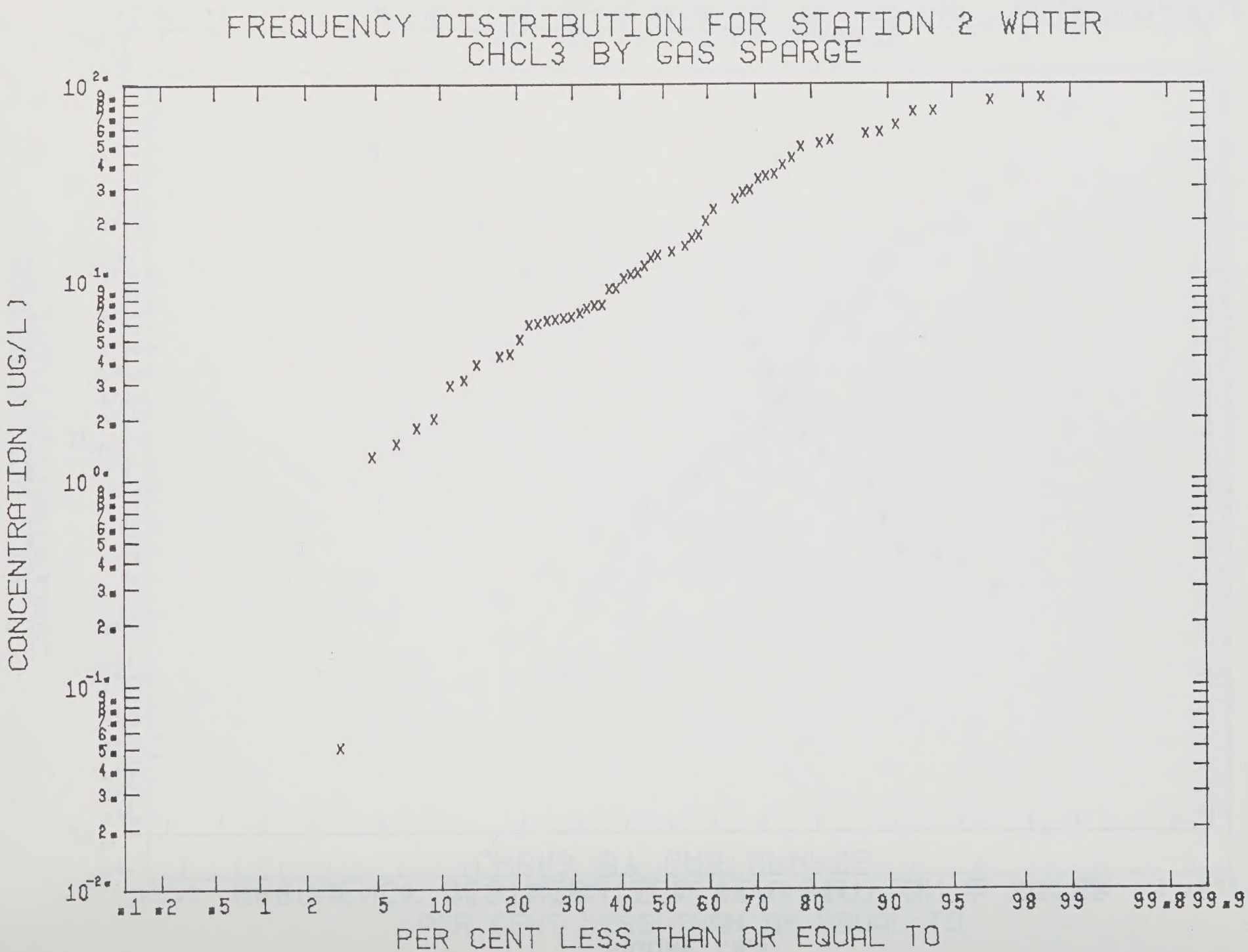

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCL3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.4.2

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCL2BR BY GAS SPARGE

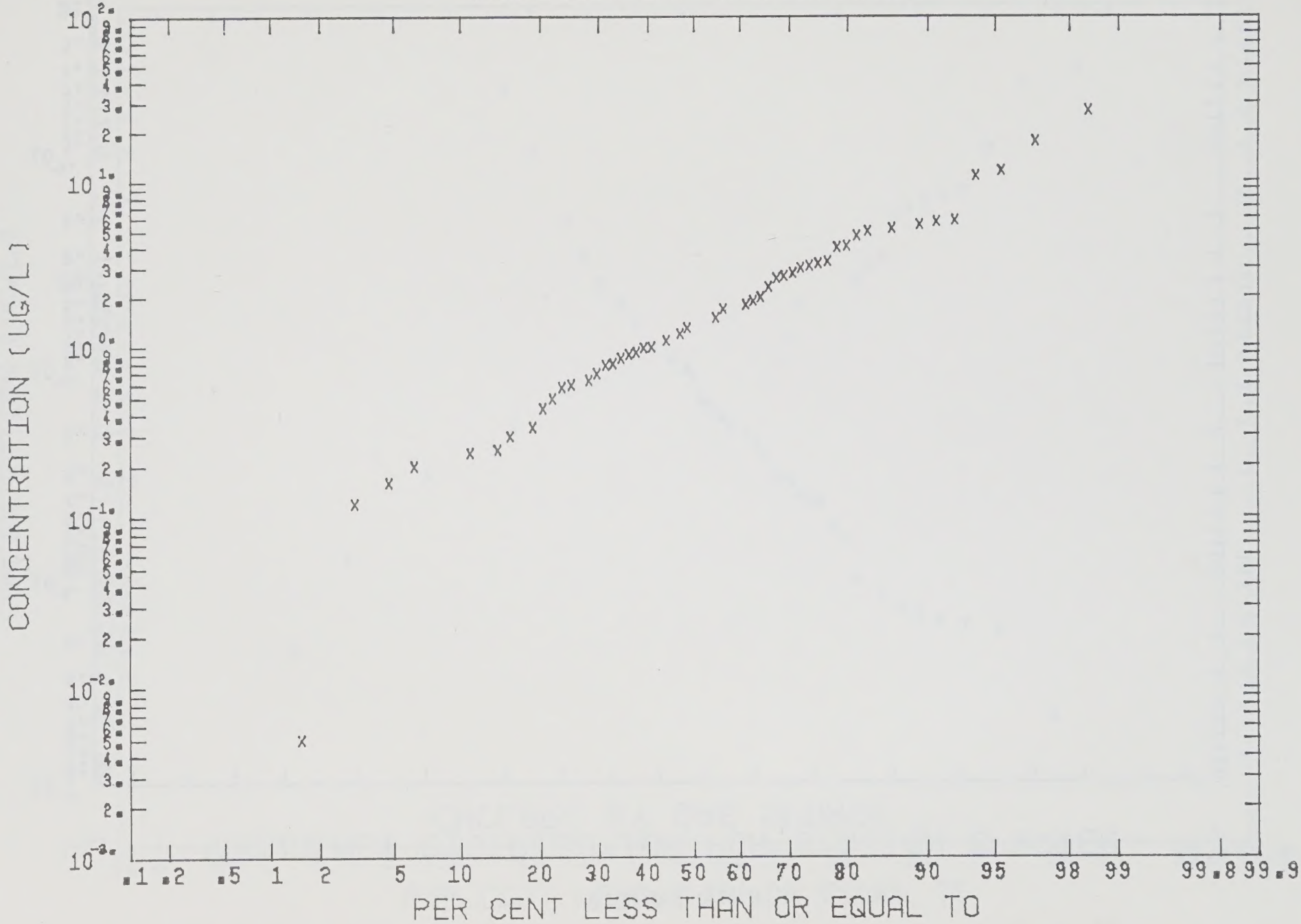


FIGURE 1.4.3

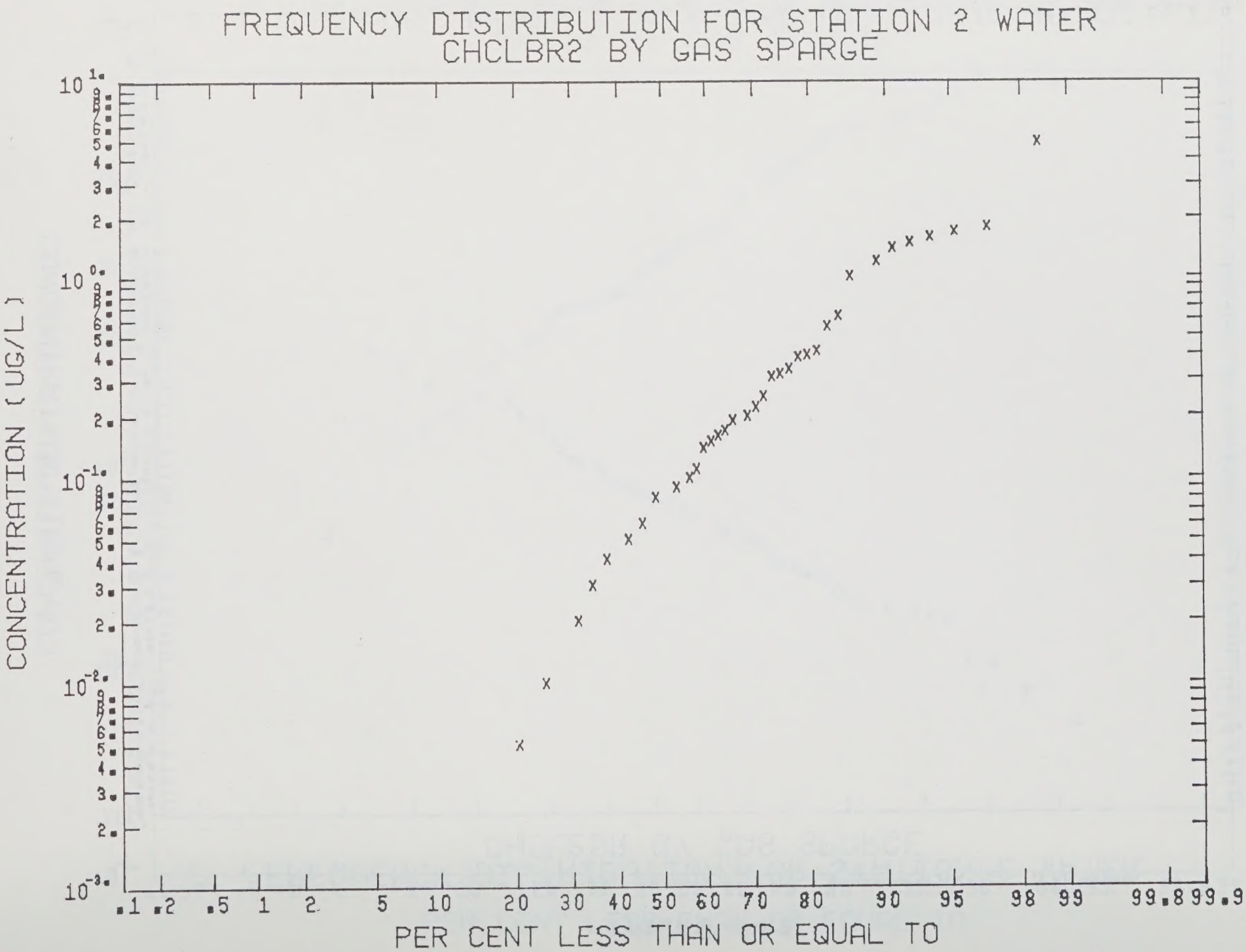

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCLBR2 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 1.4.4

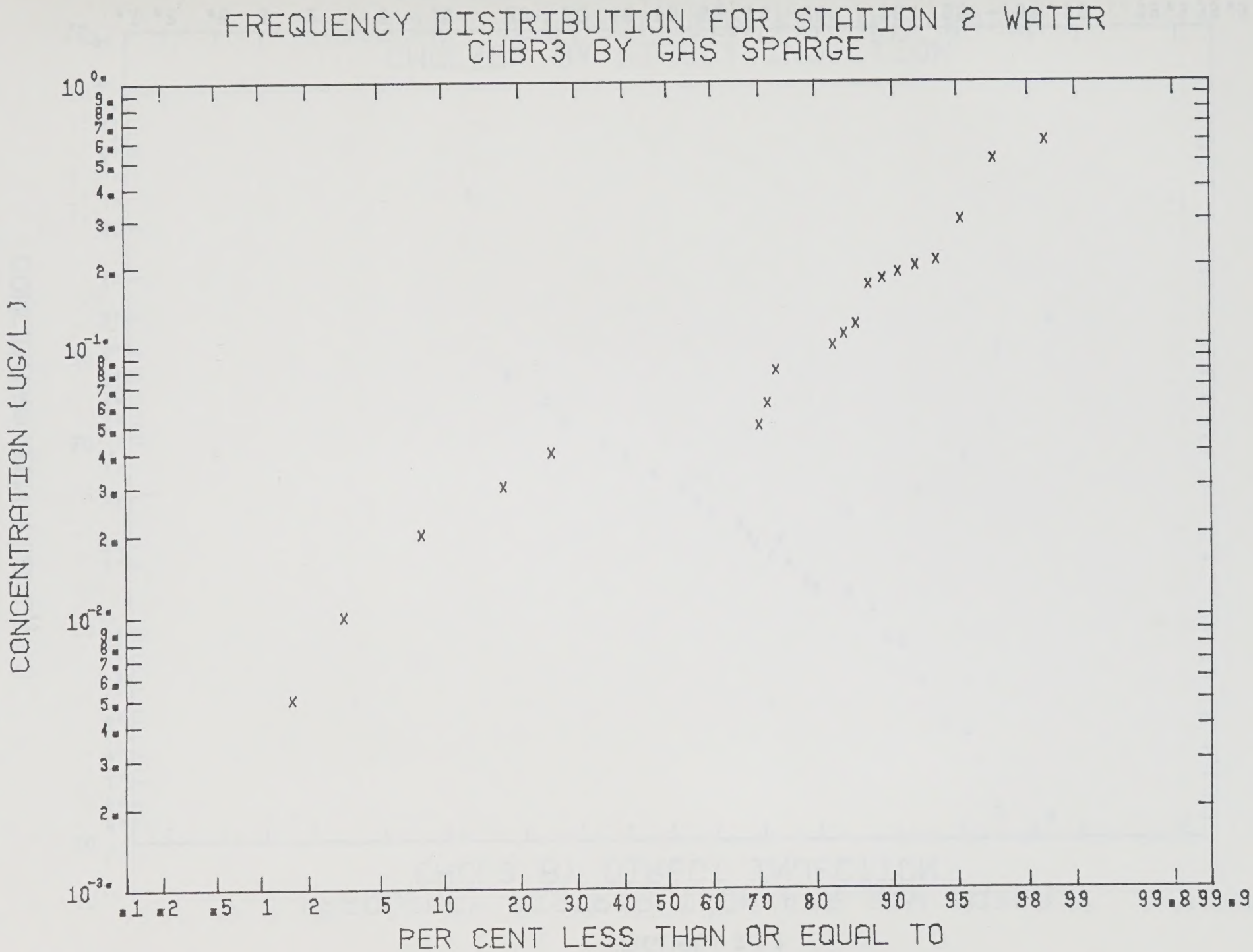

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHBR3 BY GAS SPARGE
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.1.1

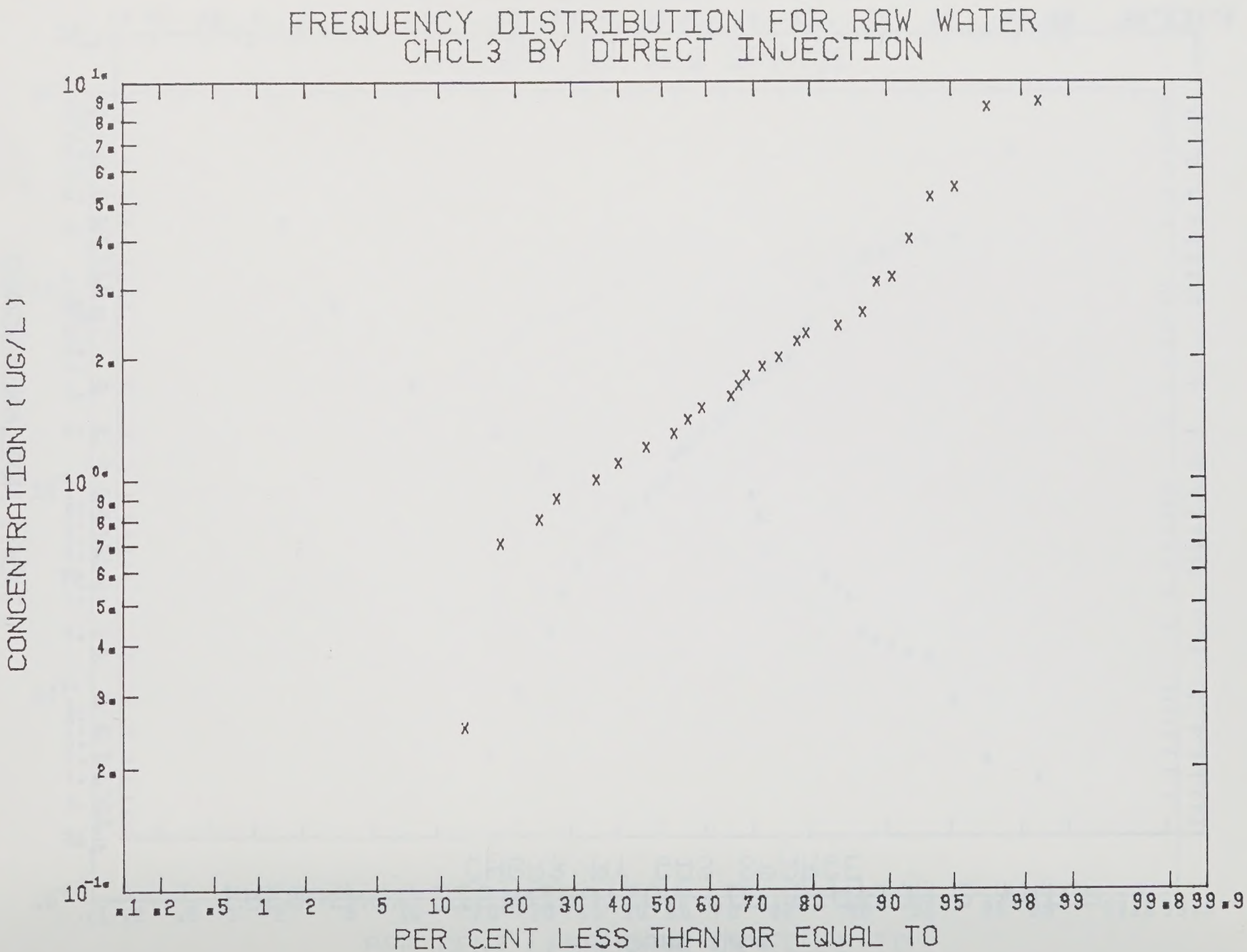

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCL3 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
10^1.
10^0.
10^-1.
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 2.1.2

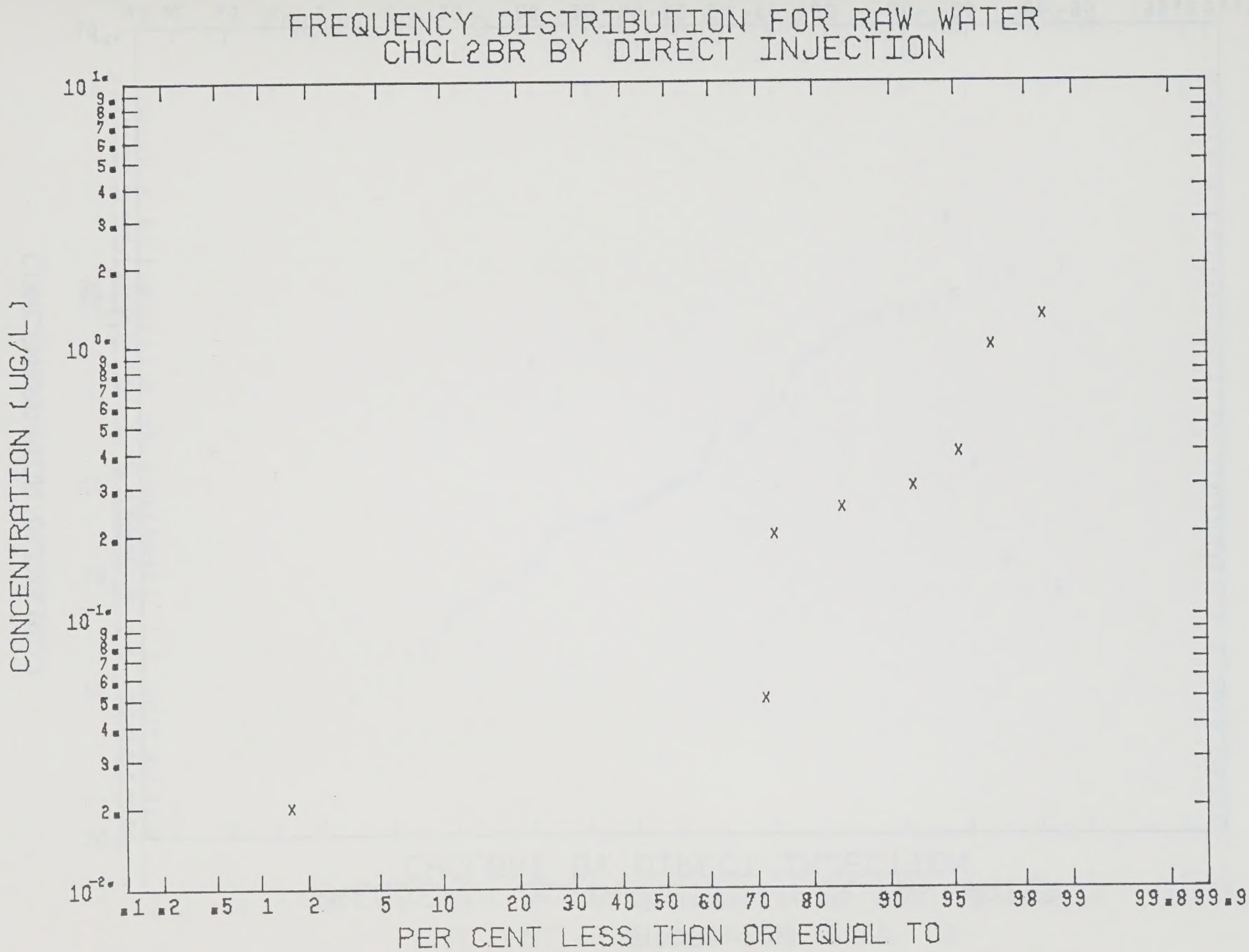

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCL2BR BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
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FIGURE 2.1.3

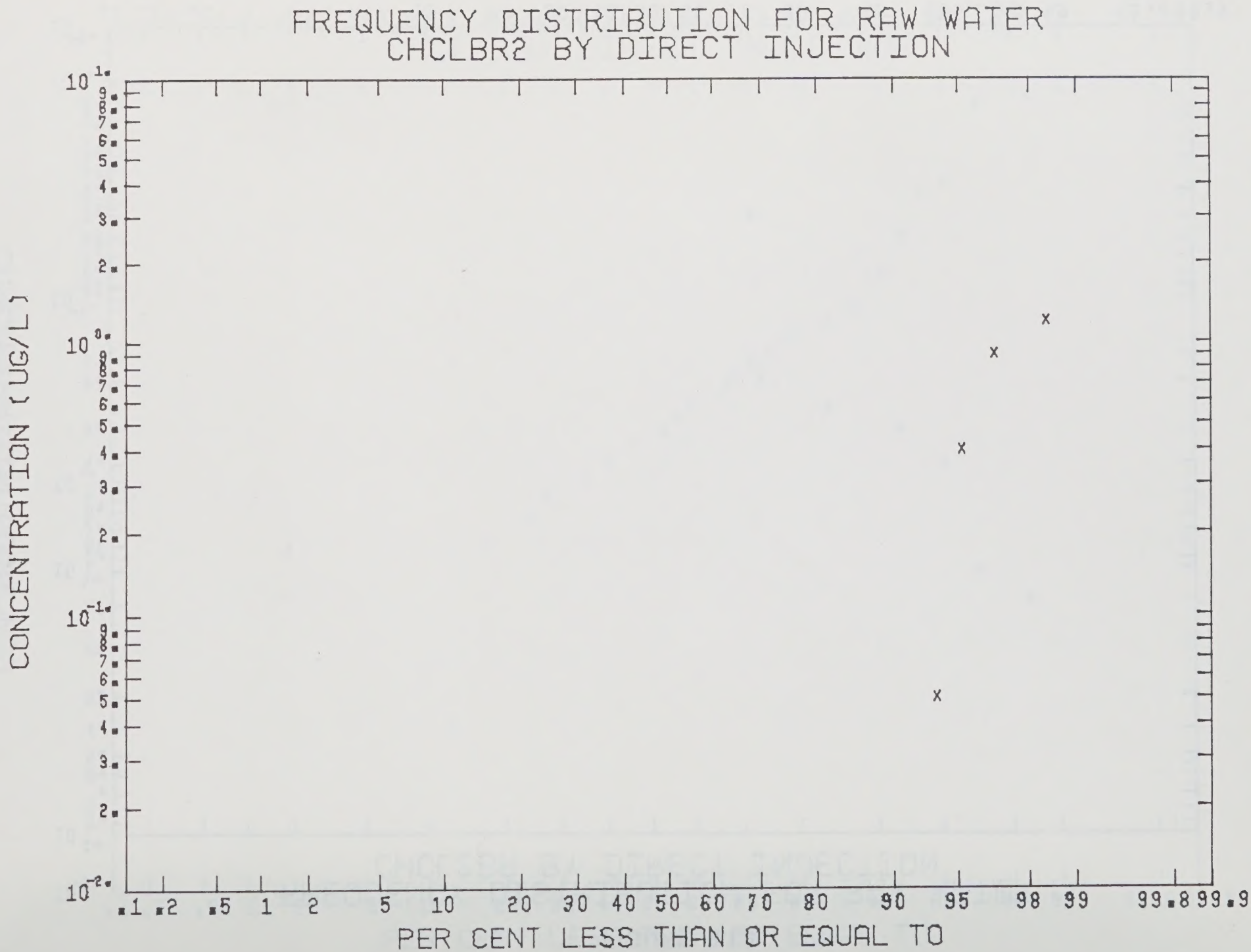

FREQUENCY DISTRIBUTION FOR RAW WATER
CHCLBR2 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.2.1

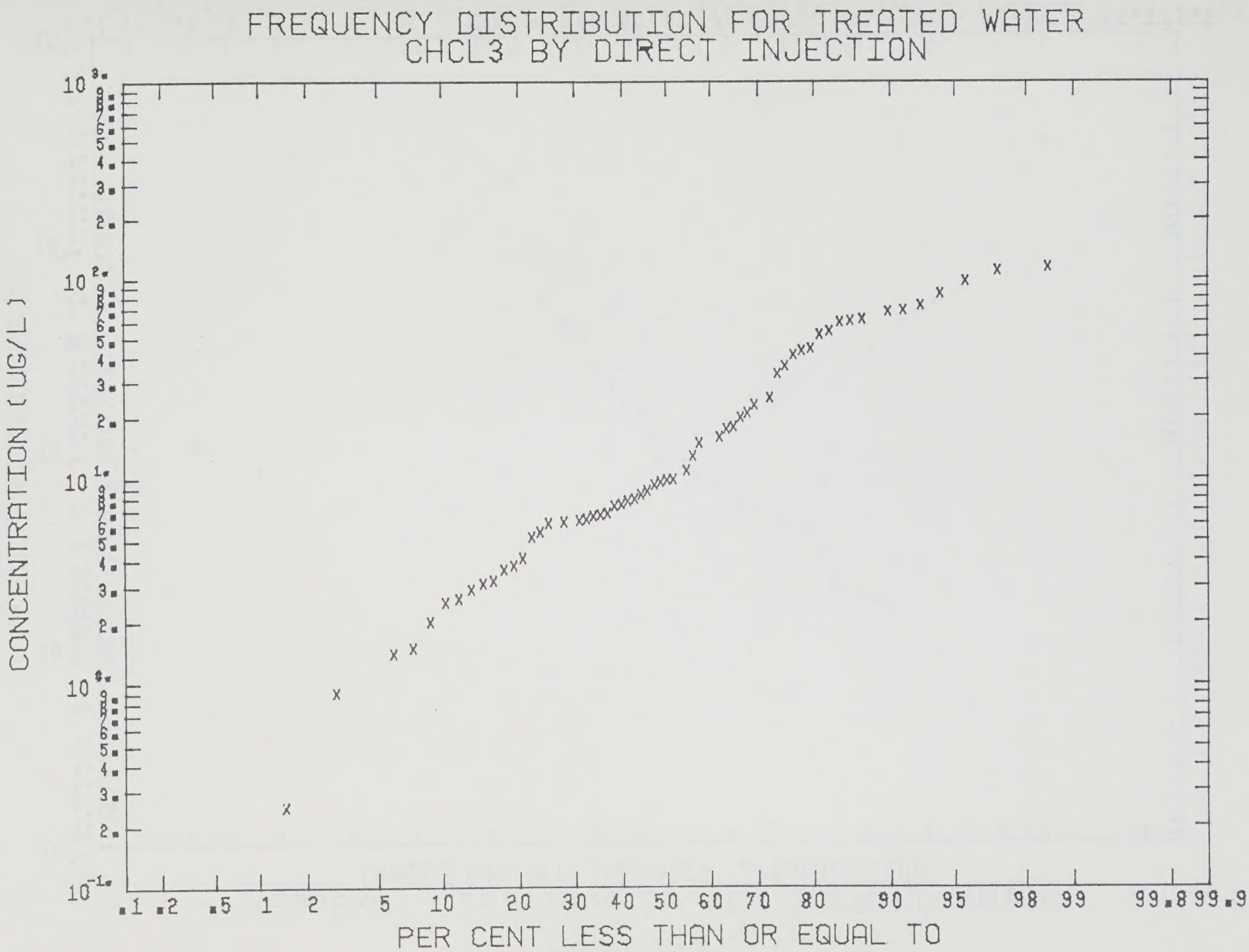

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCL3 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 2.2.2

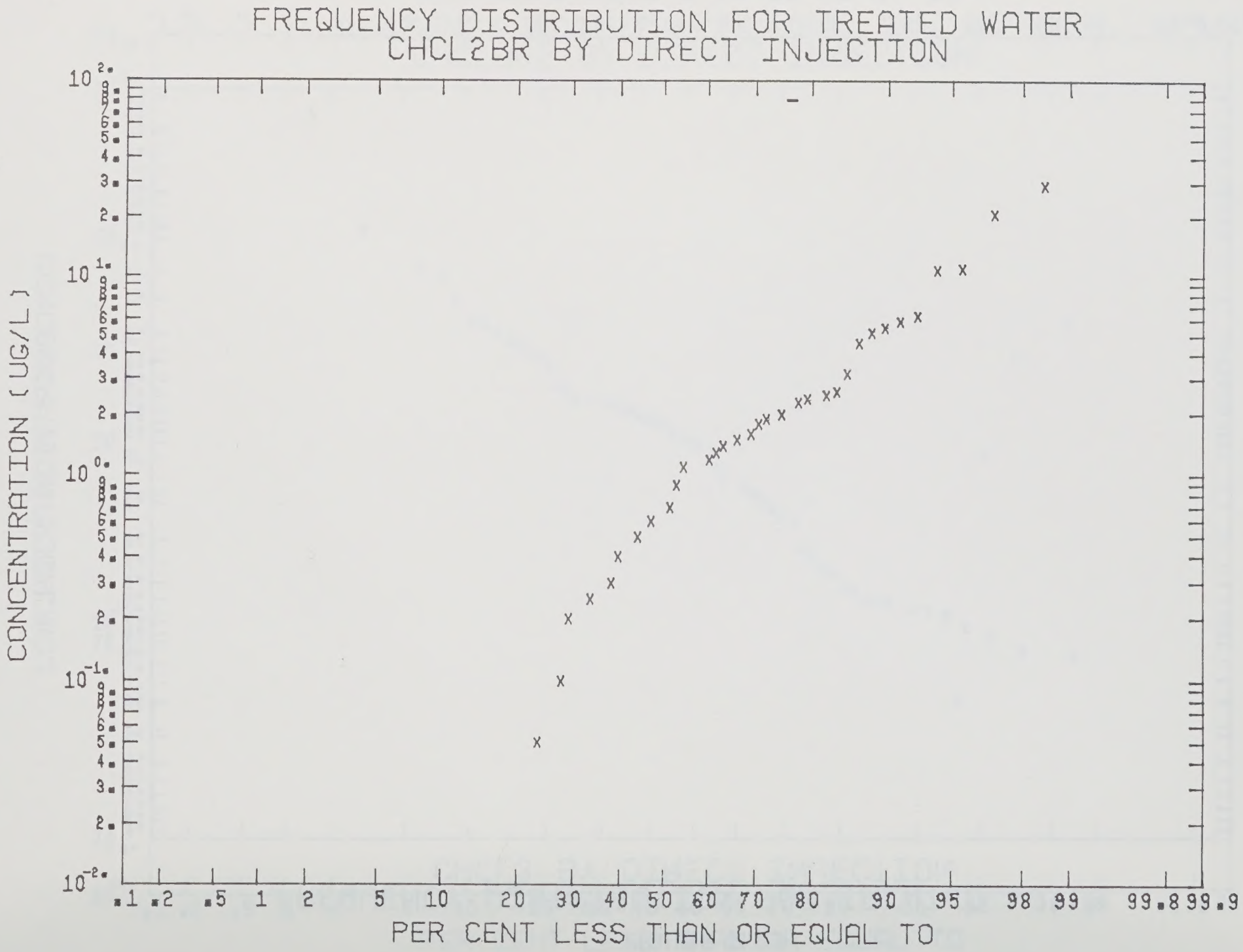

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCL2BR BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.2.3

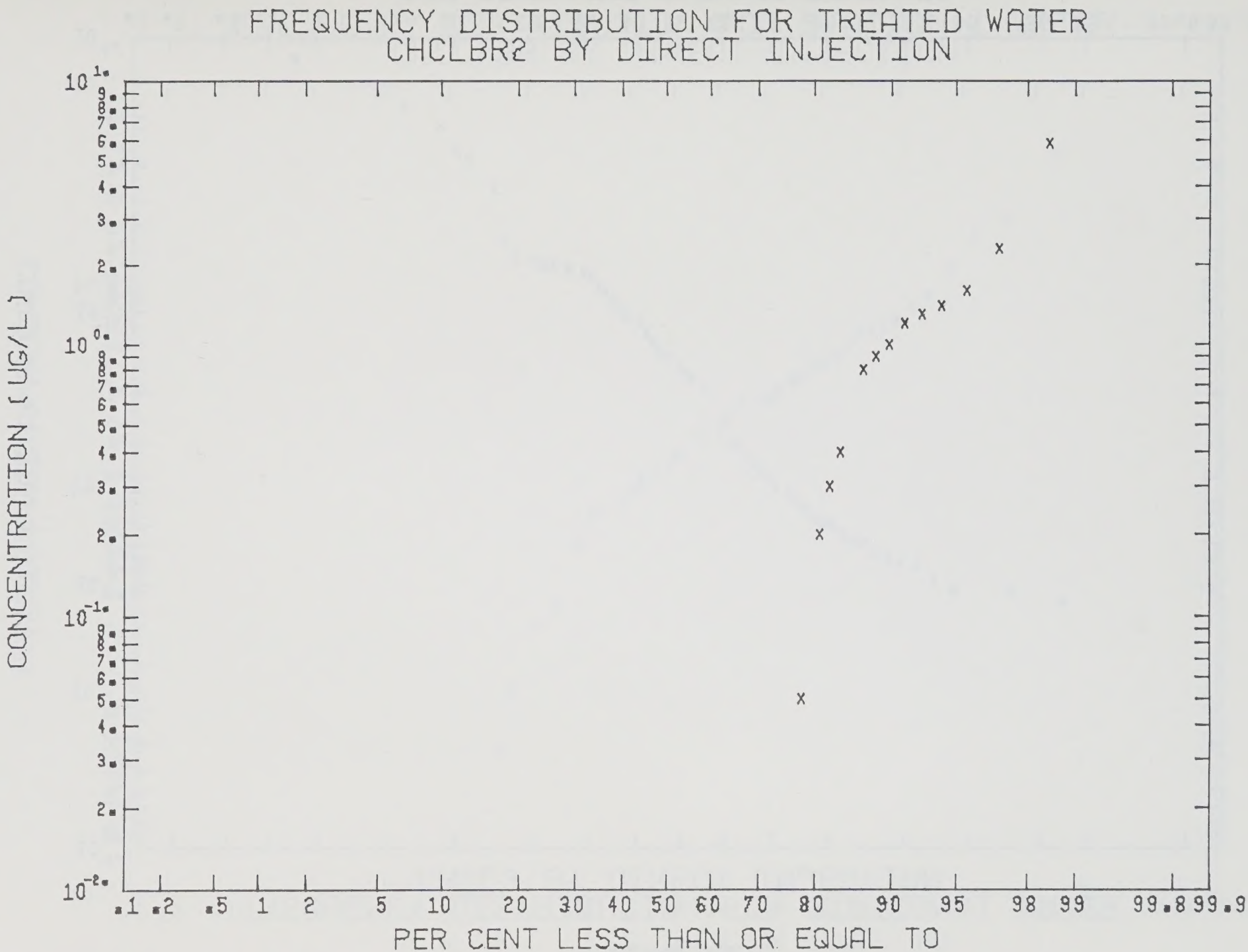

FREQUENCY DISTRIBUTION FOR TREATED WATER
CHCLBR2 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.3.1

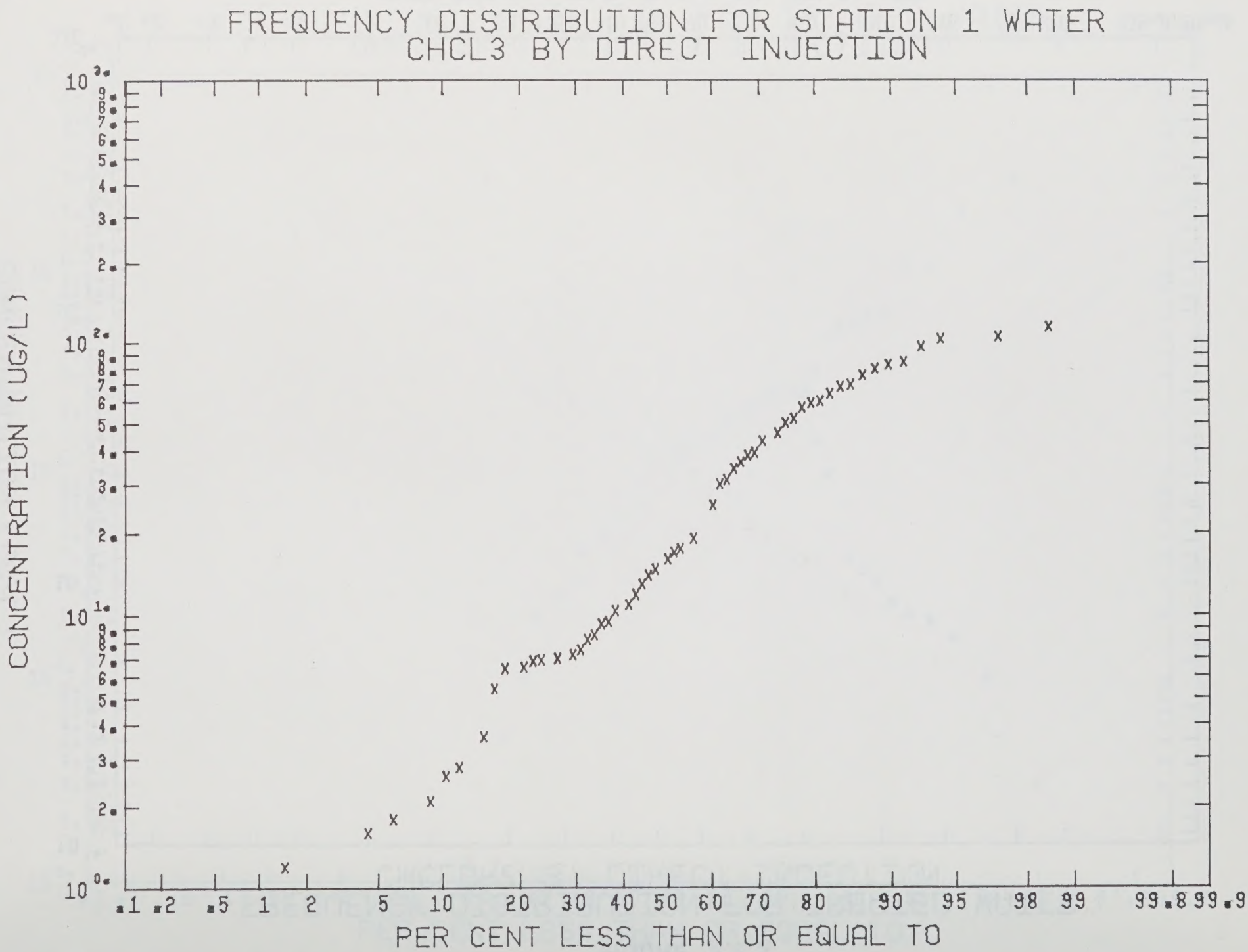

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCL3 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 2.3.2

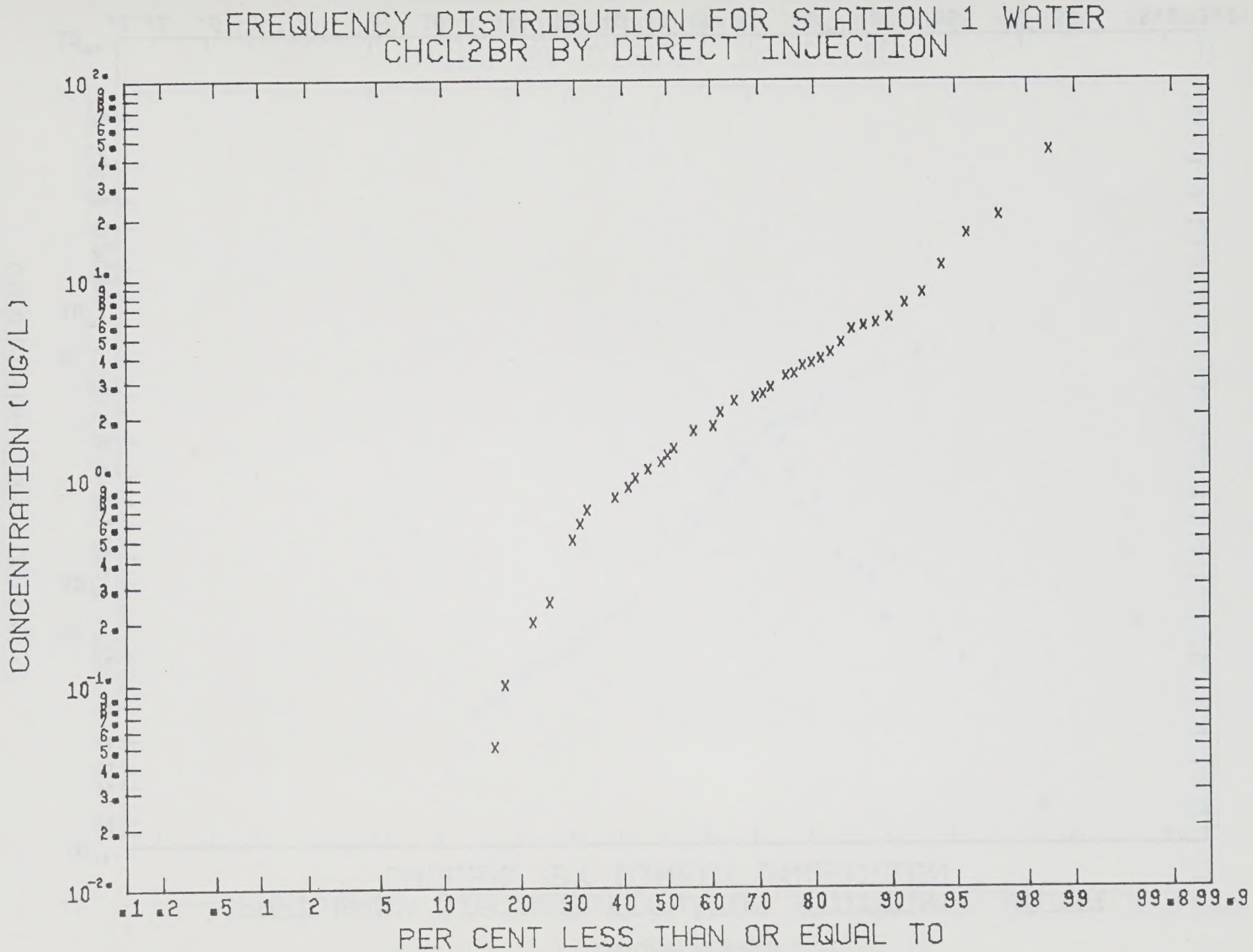

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCL2BR BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 2.3.3

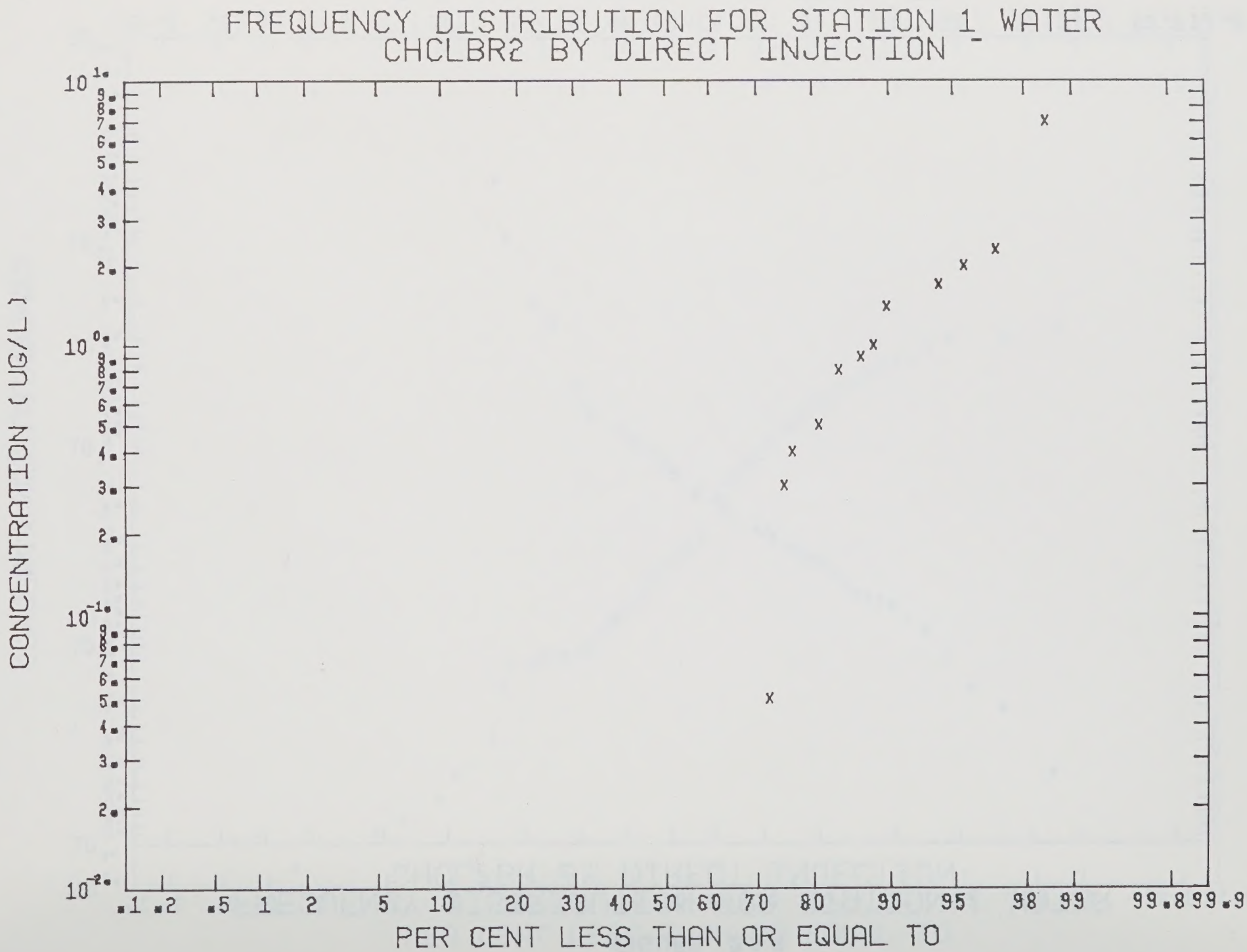

FREQUENCY DISTRIBUTION FOR STATION 1 WATER
CHCLBR2 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.4.1

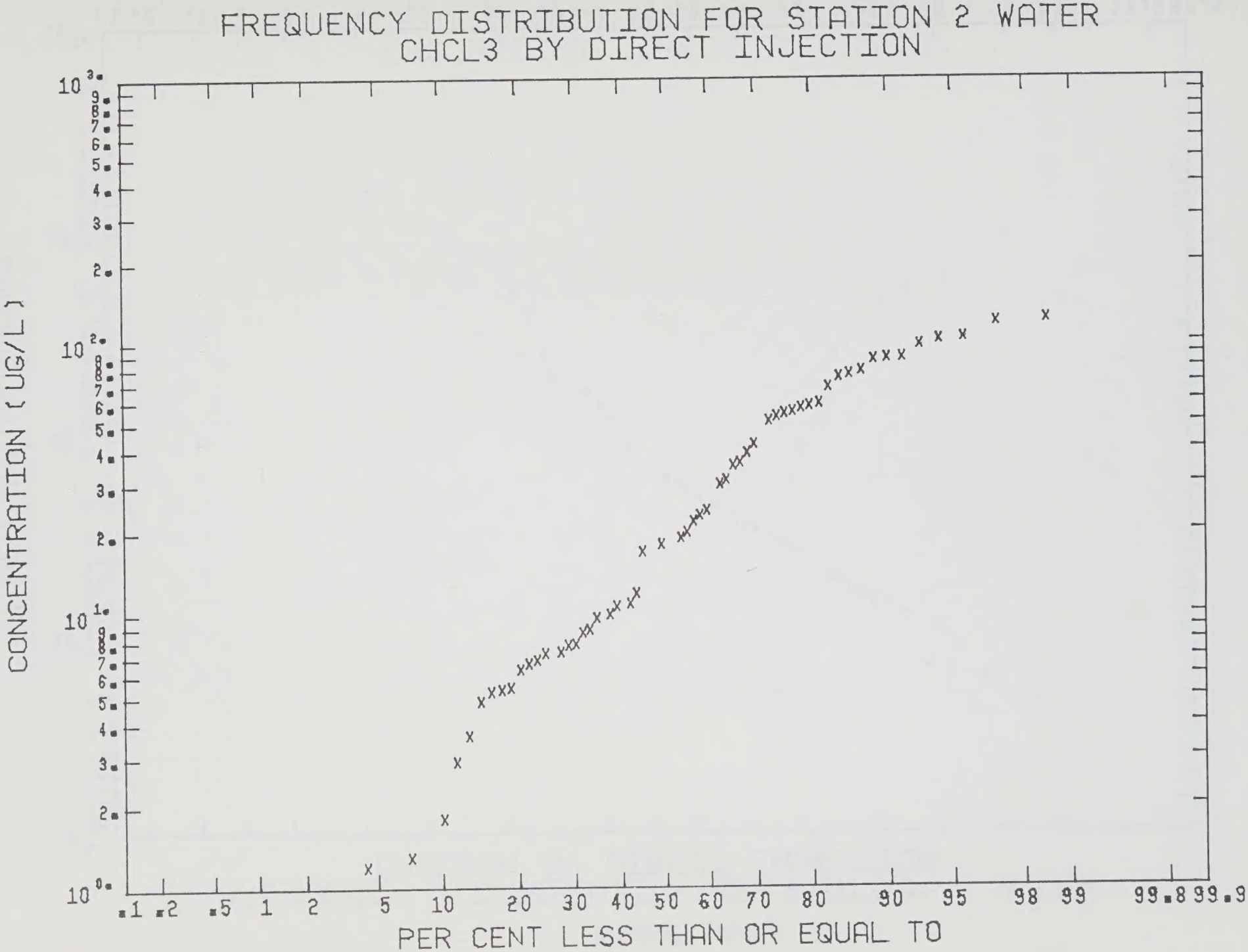

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCL3 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

FIGURE 2.4.2

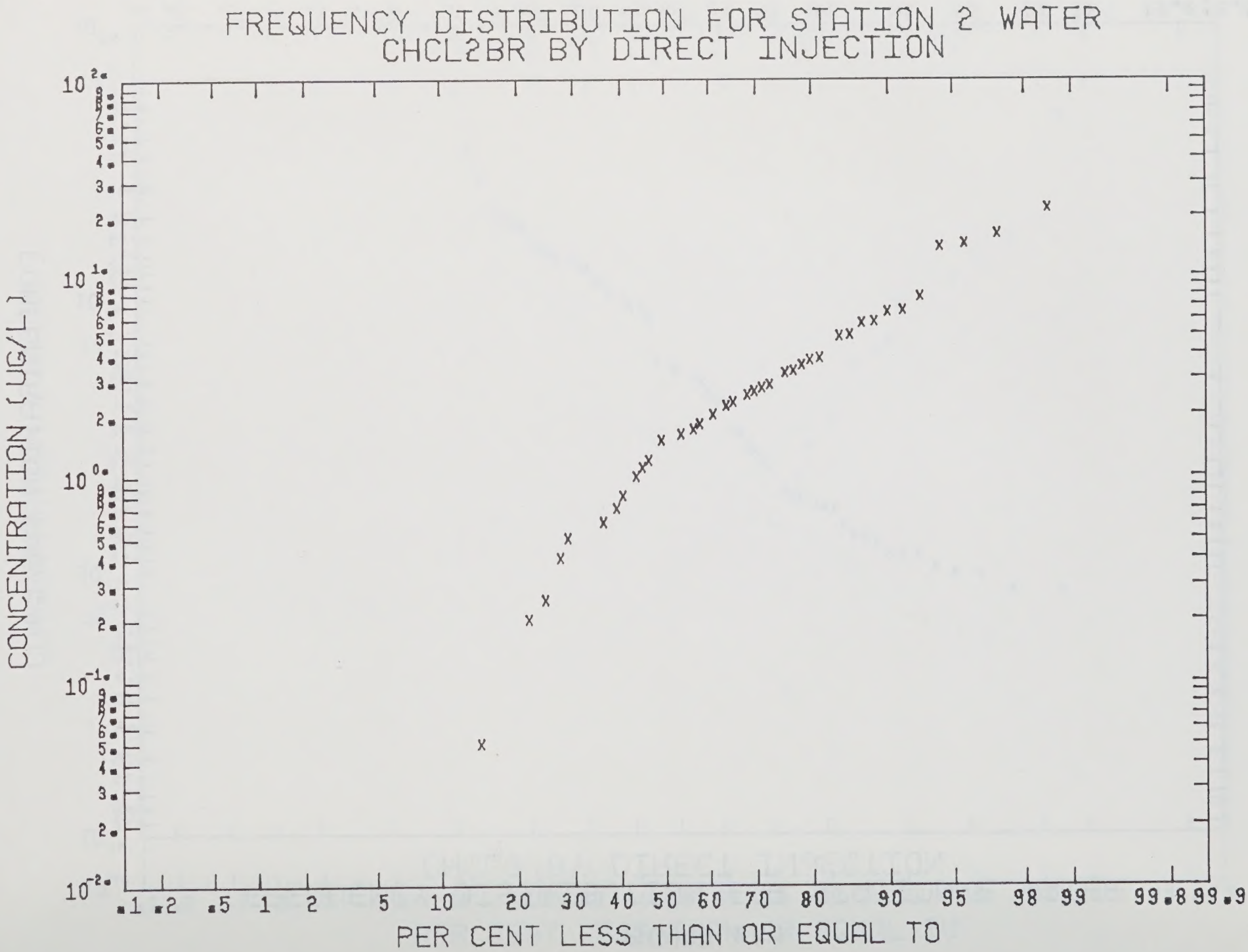
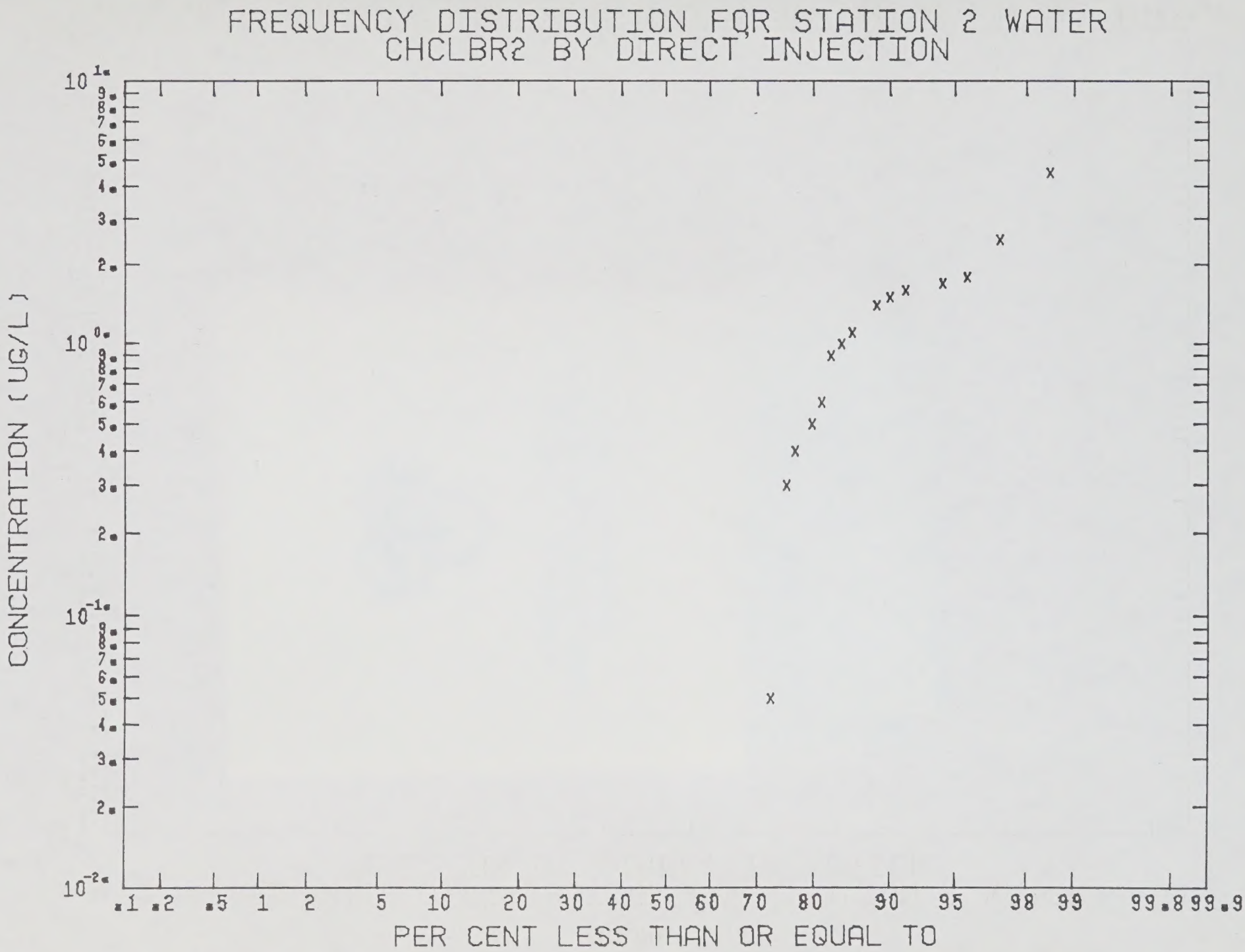

FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCL2BR BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO
.1 .2 .5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9

FIGURE 2.4.3


FREQUENCY DISTRIBUTION FOR STATION 2 WATER
CHCLBR2 BY DIRECT INJECTION
CONCENTRATION (UG/L)
PER CENT LESS THAN OR EQUAL TO

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NATIONAL SURVEY FOR HALOMETHANES IN DRINKING
1977.

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UNIVERSITY OF TORONTO